UAI8-31900 FR 1
VOL III

(NASA-CR-158720) NASTRAN HYDROELASTIC MODAL STUDIFS. VOLUME 3: NASTRAN 3-D HYDROELA.TIC ANALYSIS AND MESHGEN USER'S MANUALS Final Report (Universal Analytics, Inc.) 139 p HC A07/MF A01 CSCL 20D G3/34

N79-25353

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UNIVERSAL ANALYTICS INC

Los Angeles

FINAL REPORT
NASTRAN HYDROELASTIC MODAL STUDIES

VOLUME III

NASTRAN 3-D HYDROELASTIC ANALYSIS AND MESHGEN USER'S MANUALS

Prepared for

National Aeronautics and Space Administration
Marshall Space Flight Center

Under Contract No. NAS8-31900

May 31, 1977

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FOREWORD

This volume contains the User Documentation for the NASTRAN 3-D Analysis and the companion MESHGEN Data Generator Program. Each major section contains the descriptions of the input data as well as many examples of using the programs.

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6.0 NASTRAN 3-D HYDROELASTIC ANALYSIS USER MANUAL

6.1 INTRODUCTION

The three-dimensional hydroelasticity capability installed in NASTRAN allows the solution of problems involving interacting, arbitrarily-shaped structures and fluids. The program is intended for the vibration analysis of fluid-filled tanks in an acceleration field where the fluid motions interact with the structure displacements. Both free surface sloshing modes and higher frequency coupled modes may be obtained from the analysis.

The method used to formulate the fluid/structure equations is described in the updates to the NASTRAN Theoretical Manual. The basis for defining the fluid are three-dimensional finite elements connected to fluid grid points defining the Eulerian pressure at a point fixed in space. The use of a pressure single degree of freedom at each point rather than three displacements allows a finer mesh of elements with a reasonable matrix order.

In the formulation of the fluid/structure system the interior fluid degrees of freedom are transformed and removed from the solution matrices. The eigenvalues of the combination are extracted from small, fully dense, symmetric mass and stiffness matrices, efficiently processed with the "Givens" method. The solution matrices are defined only by the free surface displacements and the reduced structure coordinates.

All NASTRAN modeling options are available for the definition of the structure. All existing options for NASTRAN Executive Control and Case Control data for normal modes analysis are also available for the hydroelastic problems. In addition to the normal NASTRAN data, a hydroelastic problem requires the addition of a finite element fluid model, the specification of its boundaries, and the addition of special control data. The set-up of the hydroelastic NASTRAN data decks is illustrated in the examples at the end of this document.

For hydroelastic analysis the fluid is modeled with three-dimensional finite elements having shapes defined by tetrahedra (FTETRA), wedge (FWEDGE) and hexagonal (FHEX1 or FHEX2) volumes. The fluid is assumed to be locally incompressible and non-visious with small motions relative to the overall free body displacements of the system. The following options are provided for defining the fluid boundary conditions.

1. The default boundary is a rigid wall.
2. Pure free surfaces are defined with single point constraints.
3. Free surfaces with gravity effects are specified with CFFREE data cards.
4. Fluid/structure boundaries are defined by CFLSTR data cards.

Several alternate paths are available for the execution of the problem and formulation of the solution equations. These are:

1. <u>Direct versus Modal Structure Formulation</u>

In the "direct" formulation the solution matrices are defined by the structure degrees of freedom (after constrained and omitted points are removed) plus one degree of freedom for each free surface point defined on CFFREE data. The alternate "modal" formulation calculates the modes of the empty structure and uses the generalized displacements of these modes with the free surface degrees of freedom in the solution matrix formulation. Although the modal formulation requires the additional cost of another eigenvalue extraction process, the combination system matrices will be smaller. This method is recommended for problems where several different fluid models are used with the same structure model. The structure modes need only be calculated once. Different fluid models may be analyzed using the NASTRAN restart procedure to recover the structure mode data.

2. Compressibility Options

Two methods are provided for defining the compressible fluid effects. The overall compressibility of the enclosed volume may be specified as a parametric number which, in effect, provides a stiffness factor applied to the total volume change. The alternate method produces zero volume change by automatically constraining one degree of freedom in the system. The latter method is not allowed in the model formulation option.

3. Differential Stiffness Effects (Ullage Pressure)

An option has been provided for including the effects of ullage pressure on the structure stiffness. These additional stiffness terms are calculated in a separate structure-only Rigid Format 4 analysis with pressures defined by static loads. The differential stiffness is transferred to the hydroelastic problem with the NASTRAN checkpoint/restart procedure and is controlled by two parameters, DISTIF and DIFSCALE.

In the following sections the actual NASTRAN input is described. The section on the Executive Control deck describes the overall system control and the available parametric data. The section on Case Control describes the control of optional input cases and output requests. The Bulk Data section describes the detailed formats for each new bulk data card. The final section illustrates through several examples the actual contents of the NASTRAN decks for the many optional paths through the program.

6.2 HYDROELASTIC EXECUTIVE CONTROL DECK

The hydroelastic Executive Control deck is similar to that for the existing normal modes analysis, Rigid Format 3. When running the hydroelastic analyses, the user must insert one of the special DMAP ALTER packages into his Executive Control deck. These alter cards are delivered with the modified NASTRAN system.

Two special DIAG's have been added for the hydroelastic analysis.

DIAG 23 - Prints a list of degrees of freedom including fluid point definitions. For each point, an indication is made identifying the sets to which it belongs.

DIAG 24 - Prints the contents of selected displacement sets. For each set, a list of all degrees of freedom belonging to the set is given.

These two DIAG's produce similar output to DIAG's 21 and 22 except the following hydroelastic sets are included or modified:

U_x = Structure point

U_y = Fluid point

U_{fr} = Free surface point

$U_z = U_x + U_{fr}$

U_{ab} = a bits (structure only)

U_i = Interior fluid points

$U_a = U_{ab} + U_{fr}$

Hydroelastic DMAP Alters

Two sets of DMAP alters to Rigid Format 3, Figure 1 and 2, are provided to perform the three-dimensional hydroelastic analysis. These alters will obtain the hydroelastic solution with either direct or modal formulation.

```
ALTER     1,1
XDMAP     GO,ERR=2 $
BEGIN     HYDROELASTIC ANALYSIS - DIRECT FORMULATION $
ALTER     2
COMPOFF   NEWM,NEWMODE $
ALTER     62
FLBMG     GEOM2,ECT,BGPDT,SIL,MPT,GEOM3,CSTM,USET,EQEXIN/USETF,
          USETS,AF,DKGG/S,N,NOGRAV/S,N,NOFREE/S,N,TILT $
CHKPNT    USETF,USETS,AF,DKGG $
VEC       USETF/PV1/*G*/*X*/*Y* $
CHKPNT    PV1 $
PARTN     KGG,PV1,/KXX,,,KYY $
PARTN     MGG,PV1,/MXX,,, $
PARTN     RG,PV1,/RX,,,/1 $
EQUIV     RX,RG $
CHKPNT    RG $
PARTN     AF,PV1,/,,AXY,AYY $
COND      LBL69,NOGRAV $
PARTN     DKGG,PV1,/DKXX,,,DKYY $
COND      LBL69,NOFREE $
VEC       USETF/PV2/*Y*/*FR*/*COMP* $
CHKPNT    PV2 $
PARTN     AYY,,PV2/AFRY,,,/0 $
PARTN     DKYY,PV2,/DKFRFR,,, $
LABEL     LBL69 $
CHKPNT    AFRY,AXY,KYY,DKXX,DKFRFR $
SWITCH    USET,USETS// $
CHKPNT    USET,USETS $
COMPOFF   NOSTRUC,OLDSTR $
COMPON    2,DIFSTIF $
PARAMR    //*COMPLEX*//V,Y,DIFSCALE=1.0/0.0/DIFSCAL/// $
ADD       KXX,KDGG/KGG//DIFSCAL $
COMPOFF   1,DIFSTIF $
EQUIV     KXX,KGG $
EQUIV     MXX,MGG $
CHKPNT    KGG,MGG $
ALTER     85
LABEL     NOSTRUC $
PURGE     DKAA/NOGRAV $
COND      LBL73,NOGRAV $
EQUIV     DKXX,DKNN/MPCF1 $
CHKPNT    DKNN $
COND      LBL71,MPCF2 $
MCE2      USET,GM,DKXX,,,/DKNN,,, $
CHKPNT    DKNN $
LABEL     LBL71 $
EQUIV     DKNN,DKFF/SINGLE $
CHKPNT    DKFF $
COND      LBL72,SINGLE $
SCE1      USET,DKNN,,,/DKFF,,,,, $
CHKPNT    DKFF $
LABEL     LBL72 $
EQUIV     DKFF,DKAA/OMIT $
COND      LBL73,OMIT $
SMP2      USET,GO,DKFF/DKAA $
LABEL     LBL73 $
CHKPNT    DKAA $
```

FIGURE 1. DIRECT FORMULATION DMAP ALTERS

```
GFSMA     AXY,AFRY,KYY,DKAA,DKFRFR,KAA,MAA,GM,GO,USET,USETF,,,/KMAT,
          MMAT,GIA,,HC/NOGRAV/NOFREE/V,Y,KCOMP/V,Y,COMPTYP,FORM=-1 $
CHKPNT    KMAT,MMAT,GIA,HC $
EQUIV     KMAT,KAA//MMAT,MAA $
SWITCH    USET,USETF// $
CHKPNT    USET,USETF,KAA,MAA $
ALTER     95
LABEL     NEWM $
ALTER     108,109
COND      NOCOMP,COMPTYP $
MPYAD     HC,PHIA,/PHIAC/0/1/0 $
EQUIV     PHIAC,PHIA $
LABEL     NOCOMP $
MPYAD     GIA,PHIA,/PHII/0/1/0 $
EQUIV     PHII,PHIY/NOFREE $
CHKPNT    PHIY $
COND      LBL75,NOFREE $
VEC       USET/PV3/*A*/*COMP*/*FR* $
PARTN     PHIA,,PV3/PHIAB,PHIFR,,/0 $
EQUIV     PHIAB,PHIA $
MERGE     PHIFR,PHII,,,,PV2/PHIY/0 $
LABEL     LBL75 $
SWITCH    USET,USETF// $
CHKPNT    USET,USETF $
SDR1      USET,,PHIA,,,GO,GM,,KFS,,/PHIX,,QX/1/*REIG* $
CHKPNT    PHIX,QX $
ALTER     119,119
MERGE     PHIX,PHIY,,,,PV1/PHIG/0 $
MERGE     QX,,,,,PV1/QG/0 $
CHKPNT    QG,PHIG $
SDR2      CASECC,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMA,QG,PHIG,EST,,/ ,
          OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG*//TILT $
ENDALTER
```

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FIGURE 1. DIRECT FORMULATION DMAP ALTERS (Cont'd)

```
ALTER     1,1
XDMAP     GO,ERR=2 $
BEGIN     HYDROELASTIC ANALYSIS - MODAL FORMULATION
ALTER     2
COMPOFF   NEW1,NEWMODE $
ALTER     62
FLBMG     GEOM2,ECT,BGPDT,SIL,MPT,GEOM3,CSTM,USET,EQEXIN/USETF,
          USETS,AF,DKGG/S,N,NOGRAV/S,N,NOFREE/S,N,TILT $
CHKPNT    USETF,USETS,AF,DKGG $
VEC       USETF/PV1/*G*/*X*/*Y* $
CHKPNT    PV1 $
PARTN     KGG,PV1,/KXX,,,KYY $
PARTN     MGG,PV1,/MXX,,, $
PARTN     RG,PV1,/PX,,,/1 $
EQUIV     RX,RG $
CHKPNT    RG $
PARTN     AF,PV1,/,,AXY,AYY $
COND      LBL69,NOGRAV $
PARTN     DKGG,PV1,/DKXX,,,DKYY $
COND      LBL69,NOFREE $
VEC       USETF/PV2/*Y*/*FR*/*COMP* $
CHKPNT    PV2 $
PARTN     AYY,,PV2/AFRY,,,/0 $
PARTN     DKYY,PV2,/DKFRFR,,, $
LABEL     LBL69 $
CHKPNT    KYY,DKXX,DKFRFR,AXY,AFRY $
LABEL     NEW1 $
DPD       DYNAMICS,GPL,SIL,USET/GPLD,SILD,USETD,,,,,,,EED,EQDYN/
          LUSET/LUSETD/NOTFL/NODLT/NOPSDL/NOFRL/NONLFT/NOTRL/S,N,NOEED/
          /NOUE $
COND      ERROR2,NOEED $
CHKPNT    EED $
COMPOFF   NEW2,NEWMODE $
SWITCH    USET,USETS// $
CHKPNT    USET,USETS $
PARAM     //*MPY*/CARDNO/0/0 $
COMPOFF   NOSTRUC,CLOSTR $
COMPON    2,DIFSTIF $
PARAMR    //*COMPLEX*//V,Y,DIFSCALE=1.0/0.0/DIFSCAL/// $
ADD       KXX,KDGG/KGG//DIFSCAL $
COMPOFF   1,DIFSTIF $
EQUIV     KXX,KGG $
EQUIV     MXX,MGG $
CHKPNT    KGG,MGG $
ALTER     96,99
CASE      CASECC,/CASE1/*REIGEN*/S,N,REPT/S,N,LOLP $
CHKPNT    CASE1 $
ALTER     104,104
ALTER     110,119
MERGE     PHIG,,,,,PV1/PHIGS/0 $
MERGE     QG,,,,,PV1/QGS/0 $
SDR2      CASE1,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDT,LAMA,QGS,PHIGS,EST,,/,
          OQGS,OPHIGS,,OEFS,PPHIGS/*REIG* $
OFP       OPHIGS,OQGS,OEFS,,,//S,N,CARDNO $
LABEL     NOSTRUC $
PURGE     DKAA/NOGRAV $
COND      LBL73,NOGRAV $
```

FIGURE 2. MODAL FORMULATION DMAP ALTERS

```
EQUIV     DKXX,DKNN/MPCF1 $
CHKPNT    DKNN $
COND      LBL71,MPCF2 $
MCE2      USET,GM,DKXX,,,/DKNN,,, $
CHKPNT    DKNN $
LABEL     LBL71 $
EQUIV     DKNN,DKFF/SINGLE $
CHKPNT    DKFF $
COND      LBL72,SINGLE $
SCE1      USET,DKNN,,,/DKFF,,,,, $
CHKPNT    DKFF $
LABEL     LBL72 $
EQUIV     C.FF,DKAA/OMIT $
COND      LBL73,OMIT $
SMP2      USET,GO,DKFF/DKAA $
LABEL     LBL73 $
CHKPNT    DKAA $
GFSMA     AXY,AFRY,KYY,DKAA,DKFRFR,,,,,,USETF,PHIA,PHIG,LAMA/
          KMAT,MMAT,GIH,PV4,/NOGRAV/NOFREE/V,Y,KCOMP/V,Y,COMPTYP/
          FORM=1/S,Y,LMODES $
CHKPNT    KMAT,MMAT,GIH,PV4 $
SWITCH    USET,USETF// $
CHKPNT    USET,USETF $
LABEL     NEW2 $
CASE      CASECC,/CASE2/*REIGEN*/S,N,REPT/S,N,LOLP $
CHKPNT    CASE2 $
PARAM     //*MPY*/NEIGV/1/-1 $
READ      KMAT,MMAT,,,EED,USET,CASE2/LAMAT,PHIH,MH,OEIGH/*MODES*/
          S,N,NEIGV $
CHKPNT    LAMAT,PHIH,MH,OEIGH $
OFP       LAMAT,OEIGH,,,,//S,N,CARDNO $
COND      FINIS,NEIGV $
MPYAD     GIH,PHIH,/PHII/0/1/0 $
EQUIV     PHIH,PHIZ/NOFREE $
EQUIV     PHII,PHIY/NOFREE $
COND      LBL75,NOFREE $
PARTN     PHIH,,PV4/PHIZ,PHIFR,,/0 $
MERGE     PHIFR,PHII,,,,PV2/PHIY/0 $
LABEL     LBL75 $
COND      ALLMODES,LMODES
TRAILER   PHIG//*STORE*/1/V,Y,LMODES $
TRAILER   QG//*STORE*/1/V,Y,LMODES $
LABEL     ALLMODES $
MPYAD     PHIG,PHIZ,/PHIX/0/1/0 $
MPYAD     QG,PHIZ,/QX/0/1/0 $
CHKPNT    PHIX,QX $
PLTTRAN   BGPDT,SIL/BGPDP,SIP/V,N,LUSET/V,N,LUSEP $
MERGE     PHIX,PHIY,,,,PV1/PHIGT/0 $
MERGE     QX,,,,,PV1/QGT/0 $
CHKPNT    PHIGT,QGT,BGPDP,SIP $
SDR2      CASE2,CSTM,MPT,DIT,EQEXIN,SIL,,,BGPDP,LAMAT,QGT,PHIGT,EST,,/,
          OQG1,OPHIG,OES1,OEF1,PPHIG/*REIG*//TILT $
ENDALTER
```

FIGURE 2. MODAL FORMULATION DMAP ALTERS (Cont'd)

Several optional parameters may be specified by the user for each type of solution. These parameters are used to: (1) control the optional computation paths, (2) specify numerical factors to be used in the formulation, and (3) allow blocks of DMAP code to be turned "off" for restart from a previous checkpoint run.

These parameters are entered in the Bulk Data deck using the PARAM card in addition to those already provided for Rigid Format 3.

Direct Formulation Parameters:

1. COMPTYP - optional - default = -1

   Controls the type of compressibility calculations performed. A negative integer will cause a finite compressibility as defined by the KCOMP parameter. A positive integer will cause a constraint equation to be generated to provide pure incompressibility.

2. KCOMP - optional - default = 1.0

   Value defines the overall compressibility of the fluid volume. The definition is fluid bulk modulus divided by total volume.

3. DIFSTIF - optional default = 1

   A negative integer value causes the differential stiffness matrix to be included for ullage pressure effects. This matrix is available from the checkpoint tape of a Rigid Format 4 solution run of the structure model.

4. DIFSCALE - optional - default = 1.0

   The differential stiffness matrix may be multiplied by the real value of this parameter.

5. NEWMODE - optional - default = 1

   A negative integer will cause all DMAP statements and alters up to the eigenvalue extraction to be skipped. This allows the user to restart

the original solution to obtain different eigenvectors without changing the DMAP alter deck.

6. <u>ØLDSTR</u> - optional - default = 1

   A negative value will cause most structure-related processing to be skipped. This allows the user to restart a previous solution, either hydro or structure only, and change the fluid model without recomputing the unchanged structure.

Modal Formulation Parameters:

1. <u>KCØMP</u> - optional - default = 1.0

   (same as direct formulation parameter)

2. <u>DIFSTIF</u> - optional - default = 1

   (same as direct formulation parameter)

3. <u>DIFSCALE</u> - optional - default = 1.0

   (same as direct formulation parameter)

4. <u>NEWMØDE</u> - optional - default = 1

   (same as direct formulation parameter)

5. <u>ØLDSTR</u> - optional - default = 1

   (same as direct formulation parameter)

6. <u>LMØDES</u> - optional - default = -1

   This integer value specifies the number of the lowest structure modes to be used when formulating the hydroelastic matrices. A negative value indicates all available modes are to be used.

6.3 HYDROELASTIC CASE CONTROL DECK

The Case Control data for normal modes analysis, Rigid Format 3, is not modified for direct hydroelastic solutions. For modal formulation, the data is similar except that two sets of subcases must be provided. The first set must select the EIGR card, METHOD= , to be used in eigenvalue extraction for the structure-only model. Several subcases may be used to define output requests for different vectors with the MØDES card. A second set of subcases is also needed to define the eigenvalue extraction and output request of the combined fluid/structure model. If the NEWMØDE or ØLDSTR parameter is used with modal formulation, only the second set of subcases, used for the complete model, is required. Several sample Case Control decks used for each formulation are shown below.

Direct Formulation:

```
TITLE =
SPC = 10
METHØD = 50
DISP = ALL
```

Modal Formulation:

```
TITLE =
SPC = 10
SUBCASE 1
    LABEL = MØDES ØF EMPTY STRUCTURE
    METHØD = 10
    DISP = NØNE
SUBCASE 2
    LABEL = MODES WITH FLUID INCLUDED
    METHOD = 20
    DISP = ALL
```

Modal Formulation with Selective Output Requests:

```
TITLE =
SPC = 10
SUBCASE 1
    LABEL - STRUCTURE MØDES 1 & 2
    METHOD = 10
    DISP = ALL
    MØDES = 2
SUBCASE 3
    LABEL - STRUCTURE MØDES 3 & 4
    DISP = NØNE
SUBCASE 5
    LABEL - FLUID/STRUCTURE MØDES 1-3
    METHØD = 20
    DISP = ALL
    MØDES = 3
SUBCASE 8
    LABEL - FLUID/STRUCTURE MØDE 4
    DISP = NØNE
```

In this example the eigenvectors for only the first two structure modes and the first three combined modes will be printed.

Hydroelastic Output Control

The structure printout and plotting Case Control requests are used to control both the fluid and structure outputs. The following data is available:

1. Structure-related data such as displacements, forces, and stresses are processed with normal NASTRAN control.
2. Fluid internal pressures are output by including their grid point identification numbers in the DISP = output request. If the fluid point is on a free surface defined by CFREE data, the actual free surface displacements will be printed.

3. Both structure and fluid elements may be plotted as undeformed shapes. The interior fluid point degrees of freedom are actually pressures and should not be plotted as deformed shapes.
4. The deformed shape of the free surface may be plotted using the "SHAPE" or "VECTØR" plot options. It is recommended that PLØTEL elements be used to define the free surface. If the fluid elements CFHEX1, CFHEX2, etc. were used in the requested plot set, all of their boundaries are plotted and result in a confused plot. An option is available in the mesh generator program, MESHGEN, to automatically generate the free surface PLØTEL data.
5. The use of modes parameter to control output requests is described under the Case Control section.

6.4 HYDROELASTIC BULK DATA

The new Bulk Data cards used for three-dimensional hydroelastic modes analysis are described on the following pages. These cards are used to define the fluid and fluid/structure interface. The tank walls and supporting structure are defined with NASTRAN structure elements. The actual tank walls must be defined by two-dimensional membrane, panel, or plate elements.

In addition to the new data cards, the following NASTRAN data cards are used for special hydroelastic purposes:

1. GRID cards are used to define the fluid points. Fluid grid points contain only one degree of freedom and may not be connected to the structure elements.
2. GRAV cards are used to define the magnitude and direction of the gravity field. The set identification numbers are referenced by the fluid boundary data cards.
3. SPC and SPC1 data cards may be used to define constraints on the fluid grid points. These constraints are used to define regions of zero pressure in the fluid, such as a free surface without gravity effects or an anti-symmetric boundary condition on a plane of symmetry. Only degree-of-freedom number 1 may be specified for a fluid grid point.

Input Data Card CFFREE Free Fluid Surface

Description: Defines those fluid elements composing the free fluid surface in a hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFFREE	EIDF	GRAVID	FACE		EIDF	GRAVID	FACE		
CFFREE	100	100	3		101	100	4		

Field	Contents
EIDF	Fluid element identification number (Integer > 0) (see Remark 1)
GRAVID	Identification number of a GRAV gravity vector set (Integer > 0)
FACE	Identification number of the face of the fluid element, EIDF, forming the free surface (0 < Integer ≤ 6) (see Remark 2)

Remarks:

1. Allowable fluid element types are CFHEX1, CFHEX2, CFTETRA, CFWEDGE.
2. The numbering conventions for solid faces are defined in the fluid element connection Bulk Data description.

Input Data Card CFHEXi Fluid Hexahedral Element Connection

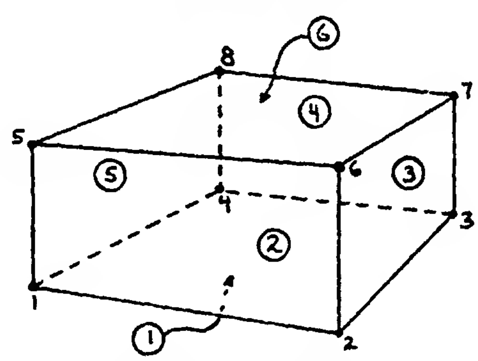
Description: Defines two types of fluid hexahedral elements (three-dimensional solid with 8 vertices and 6 quadrilateral faces) to be used in hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFHEX1	EID	MID	G1	G2	G3	G4	G5	G6	abc
CFHEX2	15	100	1	2	3	4	5	6	ABC

+bc	G7	G8							
+BC	7	8							

Field	Contents
CFHEXi	CFHEX1 or CFHEX2 (see Remark 4)
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,...,G8	Grid point identification numbers of connection points (Integer > 0, G1 $\neq$ G2 $\neq$ ... $\neq$ G8)



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.
2. The numbering and order of the grid points and faces, required for specifying free fluid surfaces, are defined in the figure above.
3. The quadrilateral faces must be nearly planar.
4. CFHEX1 is developed by 5 tetrahedra, CFHEX2 by 10 overlapping tetrahedra.
5. Material ID must reference a MAT4 Bulk Data card.

Input Data Card CFLSTR Fluid/Structure Interface

Description: Defines fluid/structure interfaces for the hydroelastic analysis.

Format and Examples:

1	2	3	4	5	6	7	8	9	10
CFLSTR	EIDF	GRAVID	EIDS1	EIDS2	EIDS3	EIDS4	EIDS5	EIDS6	abc
CFLSTR	100	10	1	2	11	12	21	22	ABC
+bc	EIDS7	EIDS8	———	etc.	———				dcf
+BC	31	32							

Alternate Form

CFLSTR	EIDF	GRAVID	EID1	"THRU"	EID2				
CFLSTR	200	100	101	THRU	106				

Field	Contents
EIDF	Fluid elements identification number (Integer > 0) (see Remark 3)
GRAVID	Identification number of a GRAV gravity vector set (Integer ≥ 0)
EIDS1,...	Structural element identification number (Integer > 0)

Remarks:

1. As many continuation cards as desired may appear when "THRU" is not used.

2. All element ID's between EID1 and EID2 must exist when using "THRU" option.

3. Allowable fluid element types are CFHEX1, CFHEX2, CFTETRA, and CFWEDGE.

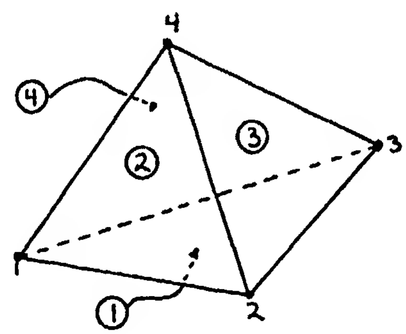
Input Data Card CFTETRA   Fluid Tetrahedral Element Connection

Description: Defines a fluid tetrahedral element (three-dimensional solid with 4 vertices and 4 triangular faces) to be used in hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFTETRA	EID	MID	G1	G2	G3	G4			
CFTETRA	25	100	1	2	3	4			

Field	Contents
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,G2,G3,G4	Grid point identification numbers of connection points (Integer > 0, $G1 \neq G2 \neq G3 \neq G4$)



Remarks: 1. Element identification numbers must be unique with respect to all other element identification numbers.

2. The numbering of the grid points and faces, required for specifying free fluid surfaces are defined in the figure above.

3. Material ID must reference a MAT4 Bulk Data card.

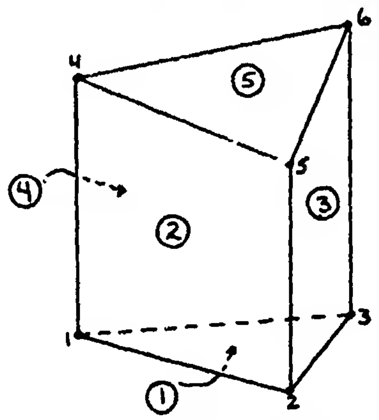
Input Data Card CFWEDGE   Fluid Wedge Element Connection

Description: Defines a fluid wedge element (three-dimensional solid, with three quadrilateral faces and two opposing triangular faces) to be used in hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
CFWEDGE	EID	MID	G1	G2	G3	G4	G5	G6	
CFWEDGE	25	100	1	2	3	4	5	6	

Field	Contents
EID	Element identification number (Integer > 0)
MID	Material identification number (Integer > 0)
G1,...,G6	Grid point identification numbers of connection points (Integers > 0; G1 ≠ G2 ≠ ... ≠ G6)



Remarks:

1. Element identification numbers must be unique with respect to all other element identification numbers.

2. The numbering of the grid points and faces, required for specifying free fluid surfaces, are defined in the figure above.

3. The quadrilateral faces must be nearly planar.

4. Material ID must reference a MAT4 Bulk Data card.

Input Data Card MATF   Fluid Material Property Definition

Description: Defines the fluid density for a hydroelastic analysis.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MATF	MID	ρ							
MATF	103	.6							

Field	Contents
MID	Material identification number (Integer > 0)
ρ	Mass density (Real > 0.0)

Remarks: 1. The material identification number may be the same as a MAT1, MAT2, or MAT3 card, but must be unique with respect to other MATF cards.

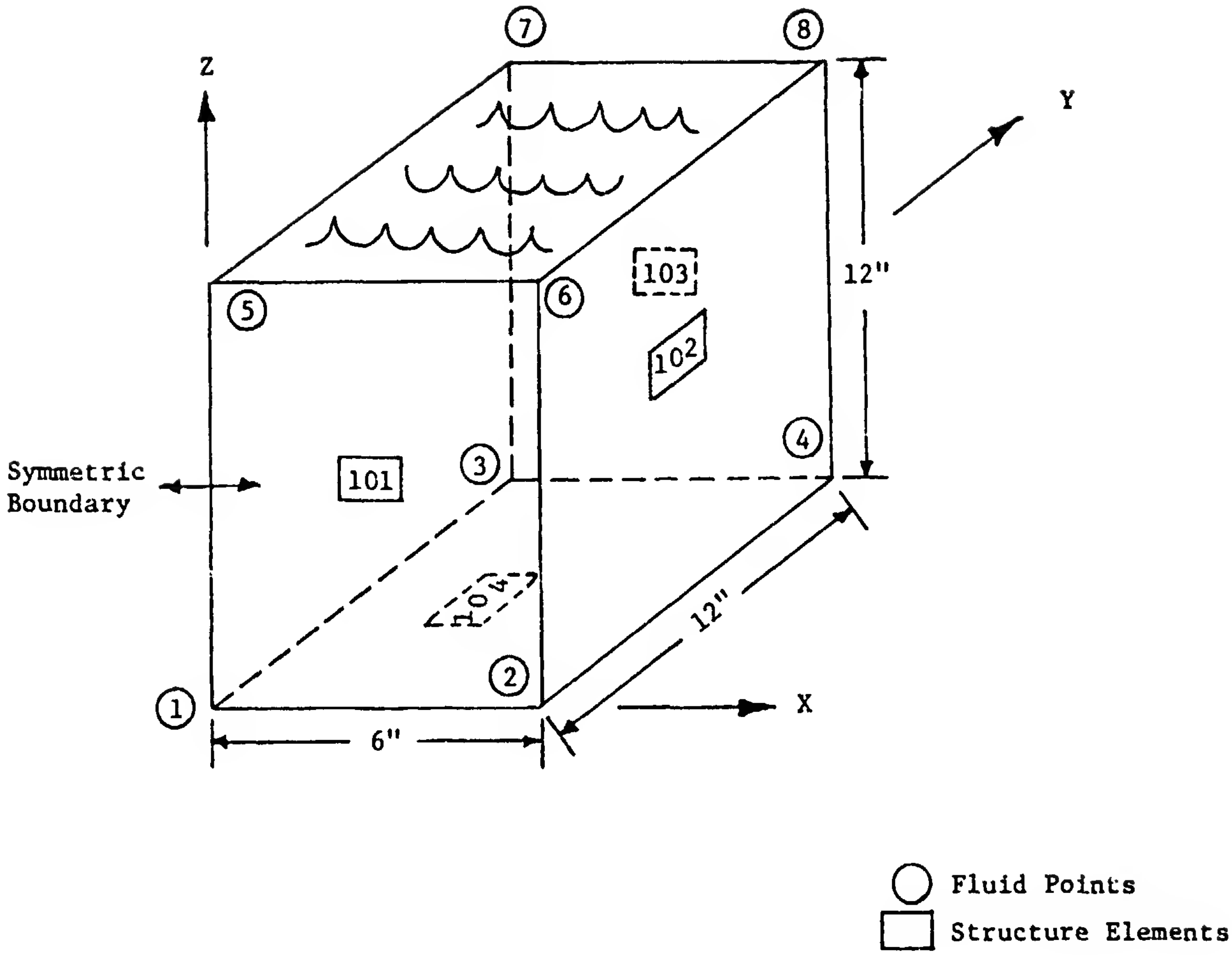


FIGURE 3. SAMPLE HYDROELASTIC MODEL

6.5 SAMPLE HYDROELASTIC PROBLEMS

In this section a set of sample hydroelastic problems are shown which demonstrate the various options available to the user. In all the problems, the same fluid/structure model is used. This model, representing a half-model of a simple box filled with fluid, is shown in Figure 3. The structure walls are modeled with CQUAD2 elements and the fluid consists of a single CFHEX2 element.

Problem I - Direct Formulation Solution

Figure 4 shows a NASTRAN deck for the solution of the sample hydroelastic Problem I.1 using the direct formulation method. In this problem, as in all following problems, the fluid grids and elements are number 1-8 and the structure grids and elements are numbered 101-108. The CFLSTR and CFFREE cards are used to define the structure/fluid boundary and the free surface respectively. This problem has been checkpointed to allow restarting for additional eigenvectors.

Figure 5 shows the restart of Problem I.1 to obtain new modes. The NEWMØDE parameter has been added to skip the recomputation of the unchanged model. In particular, the NEWMØDE parameter turns off the hydroelastic alters which would normally be re-executed during a restart. When the NEWMØDE parameter is used, the only changes that can be made are those which control the eigenvalue extraction and the output requests.

Note that when performing this type of restart, the restart dictionary should be stripped back to the start of eigenvalue extraction. For the direct formulation DMAP, this occurs at statement 96. This is to assure that the proper data blocks from the old problem tape are used in output recovery.

```
ID HYDRO,UAI
TIME 1
DIAG 8
CHKPNT YES
SOL 3,0
APP DISP
$
$ (DIRECT FORMULATION ALTERS)
$
CEND
TITLE = HYDRO ELASTIC DIRECT FORMULATION TEST
SUBTITLE = PROBLEM I.1 - FULL SOLUTION WITH CHECKPOINT
     SPC = 10
     METHOD = 50
     DISP = ALL
     SPCF = ALL
BEGIN BULK
GRID    1               0.0     0.0     0.0
GRID    2               6.0     0.0     0.0
GRID    3               0.0     12.0    0.0
GRID    4               6.0     12.0    0.0
GRID    5               0.0     0.0     12.0
GRID    6               6.0     0.0     12.0
GRID    7               0.0     12.0    12.0
GRID    8               6.0     12.0    12.0
GRID    101             0.0     0.0     0.0
GRID    102             6.0     0.0     0.0
GRID    103             0.0     12.0    0.0
GRID    104             6.0     12.0    0.0
GRID    105             0.0     0.0     12.0
GRID    106             6.0     0.0     12.0
GRID    107             0.0     12.0    12.0
GRID    108             6.0     12.0    12.0
CQUAD2  101     100     101     102     106     105
CQUAD2  102     100     102     104     108     106
CQUAD2  103     100     104     103     107     108
CQUAD2  104     100     101     103     104     102
CFHEX2  1       200     1       2       4       3       5       6
&C1     8       7
CFFREE  1       100     6
CFLSTR  1       100     101     THRU    104
PQUAD2  100     100     .06
MAT1    100     10.686          .3      .92-3
MATF    200     9.355-4
SPC1    10      1256    101     103     105     107
OMIT1   4       101     103     105     107
OMIT1   456     102     104     106     108
GRAV    100             386.0   0.0     0.0     -1.0
EIGR    50      GIV     0.0     20.0    6       6       0
&E1     MAX
ENDDATA
```

FIGURE 4. PROBLEM I.1 - DIRECT FORMULATION SOLUTION

ORIGINAL PAGE IS OF POOR QUALITY

```
ID HYDRO,UAI
TIME 1
DIAG 8
$
$ RESTART DICTIONARY FROM PROBLEM I.1
$ *** NOTE *** DICTIONARY SHOULD BE STRIPPED BACK TO STATEMENT NO. 85
$
SOL 3,0
APP DISP
$
$ (DIRECT FORMULATION ALTERS)
$
CEND
TITLE = HYDRO ELASTIC DIRECT FORMULATION TEST
SUBTITLE = PROBLEM I.2 - RESTART OF SOLUTION FOR ADDITIONAL MODES
ECHO = BOTH
     SPC = 10
     METHOD = 50
     DISP = ALL
     SPCF = ALL
BEGIN BULK
$
$ NEW EIGR CARD FOR DIFFERENT MODES
$
/       9       10
EIGR    50      GIV     100.0   2500.0                          0       &E
&E1     MAX
$
$ PARAMETER TO SKIP UNNEDDED DMAP
$
PARAM   NEWMODE -1
ENDDATA
```

FIGURE 5. PROBLEM I.2 - RESTART OF SOLUTION FOR NEW MODES

Problem II - Computation of Separate FLUID and STRUCTURE Models

In this problem, the structure model will be computed separately from the fluid. This case can occur when it is desired to obtain the behavior of an empty tank and then to add fluid at a later time.

Figure 6 shows the NASTRAN normal modes solution of the structure only, Problem II.1. This run has been checkpointed to allow restarting for a hydroelastic analysis.

In Figure 7, the run is shown which will add a fluid model to this structure and obtain the solution of the combined model, using the direct formulation method. Since the bulk data for the structure model is on the old problem tape, only the new cards required to define the fluid are provided.

The ØLDSTR parameter is used to skip re-computation of the structure. If the ØLDSTR parameter is used, no change to the structure or its constraints may be made.

```
ID HYDRO,UAI
TIME 1
CHKPNT = YES
DIAG 8
APP DISP
SOL 3,0
CEND
TITLE = HYDROELASTIC RESTART TEST
SUBTITLE = PROBLEM II.1 - NORMAL MODES OF STRUCTURE ONLY
LABEL = NASTRAN SOL 3,0 SOLUTION
     SPC = 10
     METHOD = 50
     DISP = ALL
     SPCF = ALL
BEGIN BULK
GRID    101             0.0     0.0     0.0
GRID    102             6.0     0.0     0.0
GRID    103             0.0     12.0    0.0
GRID    104             6.0     12.0    0.0
GRID    105             0.0     0.0     12.0
GRID    106             6.0     0.0     12.0
GRID    107             0.0     12.0    12.0
GRID    108             6.0     12.0    12.0
CQUAD2  101     100     101     102     106     105
CQUAD2  102     100     102     104     108     106
CQUAD2  103     100     104     103     107     108
CQUAD2  104     100     101     103     104     102
PQUAD2  100     100     .06
MAT1    100     10.6&6          .3      .92-3
SPC1    10      1256    101     103     105     107
OMIT1   4       101     103     105     107
OMIT1   456     102     104     106     108
EIGR    50      GIV     0.0     20.0    6       6       0               &E
&E1     MAX
ENDDATA
```

FIGURE 6. PROBLEM II.1 - NORMAL MODES OF STRUCTURE ONLY

```
ID HYDRO,UAI
TIME 1
DIAG 8
$
$ RESTART DICTIONARY FORM PROBLEM II.1
$
APP DISP
SOL 3,0
$
$ (DIRECT FORMULATION ALTERS)
$
CEND
TITLE = HYDROELASTIC RESTART TEST
SUBTITLE = PROBLEM II.2 - RESTART OF STURCTURE ONLY RUN
LABEL = NASTRAN HYDROELASTIC DIRECT FORMULATION DMAP
ECHO = BOTH
     SPC = 10
     METHOD = 60
     DISP = ALL
     SPCF = ALL
BEGIN BULK
$
$ *** NOTE - STRUCTURE BULK DATA IS ON RESTART TAPE
$
GRID    1               0.0     0.0     0.0
GRID    2               6.0     0.0     0.0
GRID    3               0.0     12.0    0.0
GRID    4               6.0     12.0    0.0
GRID    5               0.0     0.0     12.0
GRID    6               6.0     0.0     12.0
GRID    7               0.0     12.0    12.0
GRID    8               6.0     12.0    12.0
CFHEX2  1       200     1       2       4       3       5       6       &C
&C1     8       7
CFFREE  1       100     6
CFLSTR  1       100     101     THRU    104
MATF    200     9.355-4
GRAV    100             386.0   0.0     0.0     -1.0
EIGR    60      GIV     0.0     20.0    6       6       0               &E
&E2     MAX
$
$ PARAMETER TO USE INCOMPRSSIBLE CALCULATIONS
$
PARAM   COMPTYP 1
$
$ PARAMETER TO SKIP RECOMPUTATION OF UNCHANGED STRUCTURE
$
PARAM   OLDSTR  -1
ENDDATA
```

FIGURE 7. PROBLEM II.2 - RESTART WITH FLUID MODEL ADDED

Problem III - Addition of Internal Ullage Pressures

The NASTRAN differential stiffness analysis can be used to determine the effect of an internal ullage pressure on a tank filled with fluid. To perform this analysis, two runs are required. The first run is a NASTRAN Differential Staffness run on the tank structure only. A sample run, Problem III.1, is shown in Figure 8. In this run, a DMAP EXIT instruction was altered in to stop computation once the differental stiffness matrix was computed. Even though the solution was not obtained, the second subcase in Case Control is still required. The Sol 4,6 subset was used to turn off all CHKPNT instructions in the Rigid Format. A CHKPNT instruction was then altered in before the EXIT to save the Differential Stiffness matrix on the New Problem tape. This procedure reduces cost since only the one desired data block is copied to the new problem tape. Note also that an internal pressure of 1.0 was used. This value can be scaled to any desired value in the second run.

The hydroelastic analysis solution is shown in Figure 9. In this particular run, the direct formulation alters were used, but the modal formulation could also be executed. Since the structure bulk data is on the restart tape, only the cards needed to define the fluid are used. The DIFSTIF parameter is included to trigger addition of the differential stiffness to the structure. This matrix is obtained from the old problem tape and will be scaled by the DIFSCALE parameter prior to addition.

```
ID HYDRO,UAI
TIME 1
CHKPNT = YES
DIAG 8
APP DISP
SOL 4,6
ALTER 118
CHKPNT KOGG $
EXIT$
ENDALTER
CEND
TITLE = HYDROELASTIC ULLAGE PRESSURE TEST
SUBTITLE = PROBLEM III.1 - DIFFERENTIAL STIFFNESS RUN
SPC = 10
LOAD = 10
DISP = ALL
SUBCASE 1
   LABEL = STATIC SOLUTION
SUBCASE 2
   LABEL = DIFFERENTIAL STIFFNESS SOLUTION
BEGIN BULK
GRID    101             0.0     0.0     0.0
GRID    102             6.0     0.0     0.0
GRID    103             0.0     12.0    0.0
GRID    104             6.0     12.0    0.0
GRID    105             0.0     0.0     12.0
GRID    106             6.0     0.0     12.0
GRID    107             0.0     12.0    12.0
GRID    108             6.0     12.0    12.0
CQUAD2  101     100     101     102     106     105
CQUAD2  102     100     102     104     108     106
CQUAD2  103     100     104     103     107     108
CQUAD2  104     100     101     103     104     102
PQUAD2  100     100     .06
MAT1    100     10.6E6          .3      .92-3
SPC1    10      1256    101     103     105     107
PLOAD2  10      1.0     101     THRU    104
ENDDATA
```

FIGURE 8. PROBLEM III.1 - DIFFERENTIAL STIFFNESS, RUN #1

```
ID HYDRO,UAI
TIME 1
DIAG 8
$
$ RESTART DICTIONARY FROM PROBLEM III.1
$
APP DISP
SOL 3,0
$
$ (DIRECT FORMULATION ALTERS)
$
CEND
TITLE = HYDROELASTIC ULLAGE PRESSURE TEST
SUBTITLE = PROBLEM III.2 - NORMAL MODES RESTART WITH HYDROELASTIC DMAP
ECHO = BOTH
     SPC = 10
     METHOD = 50
     DISP = ALL
     SPCF = ALL
BEGIN BULK
$
$ *** NOTE - STRUCTURE BULK DATA IS ON RESTART TAPE
$
GRID    1                 0.0     0.0     0.0
GRID    2                 6.0     0.0     0.0
GRID    3                 0.0     12.0    0.0
GRID    4                 6.0     12.0    0.0
GRID    5                 0.0     0.0     12.0
GRID    6                 6.0     0.0     12.0
GRID    7                 0.0     12.0    12.0
GRID    8                 6.0     12.0    12.0
CFHEX2  1       200       1       2       4       3       5       6       &
&C1     8       7
CFFREE  1       100       6
CELSTR  1       100       101     THRU    104
MATF    200     9.355-4
OMIT1   4       101       103     105     107
OMIT1   456     102       104     106     108
GRAV    100               386.0   0.0     0.0     -1.0
EIGR    50      GIV       0.0     20.0    6       6       0               &
&E1     MAX
$
$ PARAMETERS TO TRIGGER ADDITION OF ULLAGE PRESSURE
$
PARAM   DIFSTIF -1
PARAM   DIFSCALE 14.7
ENDDATA
```

FIGURE 9. PROBLEM III.2 - DIRECT HYDROELASTIC SOLUTION WITH DIFFERENTIAL STIFFNESS ADDED

Problem IV - Modal Formulation Solution

Figure 10 shows the NASTRAN deck required for a modal formulation solution, Problem IV.1, of the sample hydroelastic model. Two subcases have been provided to control the eigenvalue extraction of the structure only and the fluid/structure combination. The bulk data provided is identical to that for the direct formulation solution in Problem I.1 except for the extra EIGR card. This run has been checkpointed for future restarts.

Figure 11 shows the restart of Problem IV.1 to obtain new modes. The NEWMØDE parameter has been added to skip the recomputation of the unchanged model. For this restart, the restart dictionary should be stripped back to the start of the eigenvalue extraction. For the modal formulation DMAP this occurs after LABEL NEW2 in the DMAP alter sequence at statement 119. Note that when performing this restart the only changes that can be made are those which control the eigenvalue extraction and output requests.

The input deck for Problem IV.3 is shown in Figure 12. This run perfroms a restart of Problem IV.1 and changes the fluid model. In this case the single CFHEX2 element has been replaced by two CFWEDGE elements. The new fluid boundary has been given on CFLSTR cards. This type of situation can occur when it is desired to know the behavior of a tank with different fluid levels. The advantage to the restart technique is the solution to the unchanged structure model need not be repeated. The ØLDSTR parameter has been included to skip these calculations and cause the structure modes to be recovered from the old problem tape. Note also that only one subcase is given in Case Control. This is because the extraction of eigenvalues for the structure only is to be skipped. Because the fluid Bulk Data cards are not in the Rigid Format restart tables, it is also necessary to change at least one grid card. In Problem IV.3, fluid grid 1 was replaced with duplicate grid as

shown in Figure 12. This change will then cause the proper modules to be re-executed and the new fluid model to be processed.

```
ID HYDRO,UAI
TIME 1
DIAG 8
CHKPNT = YES
SOL 3,0
APP DISP
$
$ (MODAL FORMULATION ALTERS)
$
CEND
TITLE = HYDRO ELASTIC MODAL FORMULATION TEST
SUBTITLE = PROBLEM IV.1 - FULL SOLUTION WITH CHECKPOINT
SPC = 10
DISP = ALL
SUBCASE 1
     LABEL = MODES OF EMPTY STRUCTURE
     METHOD = 50
SUBCASE 2
     LABEL = MODES WITH FLUID INCLUDED
     METHOD = 60
     SPCF = ALL
BEGIN BULK
GRID    1               0.0     0.0     0.0
GRID    2               6.0     0.0     0.0
GRID    3               0.0     12.0    0.0
GRID    4               6.0     12.0    0.0
GRID    5               0.0     0.0     12.0
GRID    6               6.0     0.0     12.0
GRID    7               0.0     12.0    12.0
GRID    8               6.0     12.0    12.0
GRID    101             0.0     0.0     0.0
GRID    102             6.0     0.0     0.0
GRID    103             0.0     12.0    0.0
GRID    104             6.0     12.0    0.0
GRID    105             0.0     0.0     12.0
GRID    106             6.0     0.0     12.0
GRID    107             0.0     12.0    12.0
GRID    108             6.0     12.0    12.0
CQUAD2  101     100     101     102     106     105
CQUAD2  102     100     102     104     108     106
CQUAD2  103     100     104     103     107     108
CQUAD2  104     100     101     103     104     102
CFHEX2  1       200     1       2       4       3       5       6       &C
&C1     8       7
CFFREE  1       100     6
CFLSTR  1       100     101     THRU    104
PQUAD2  100     100     .06
MAT1    100     10.6&6          .3      .92-3
MATF    200     9.355-4
SPC1    10      1256    101     103     105     107
OMIT1   4       101     103     105     107
OMIT1   456     102     104     106     108
GRAV    100             386.0   0.0     0.0     -1.0
EIGR    50      SIV     0.0     2600.0  10      10      0               &E
&E1     MAX
EIGR    60      SIV     0.0     10.0    6       6       0               &E
&E2     MAX
ENDDATA
```

FIGURE 10. PROBLEM IV.1 - MODAL FORMULATION SOLUTION

```
ID HYDRO,UAI
TIME 1
DIAG 8
$
$ RESTART DICTIONARY FROM PROBLEM IV.1
$ *** NOTE *** DICTIONARY SHOULD BE STRIPPED BACK TO LABEL NEW2
$               AT DMAP STATEMENT NO. 119
$
SOL 3,0
APP DISP
$
$ (MODAL FORMULATION ALTERS)
$
CEND
TITLE = HYDRO ELASTIC MODAL FORMULATION TEST
SUBTITLE = PROBLEM IV.2 - RESTART OF SOLUTION FOR NEW MODES
SPC = 10
DISP = ALL
SUBCASE 2
     LABEL = MODES WITH FLUID INCLUDED
     METHOD = 60
     SPCF = ALL
BEGIN BULK
$
$ NEW EIGR CARD FOR DIFFERENT MODE
$
/        11      12
EIGR     60      GIV     100.0   2500.0                          0               &E
&E2      MAX
$
$ PARAMETER TO TURN OFF UNNEEDED DMAP
$
PARAM    NEWMODE -1
ENDDATA
```

FIGURE 11. PROBLEM IV.2 - RESTART OF SOLUTION FOR NEW MODES

```
ID HYDRO,UAI
TIME 1
DIAG 8
$
$ RESTART DICTIONARY FROM PROBLEM IV.1
$
SOL 3,0
APP DISP
$
$ (MODAL FORMULATION ALTERS)
$
CEND
TITLE = HYDRO ELASTIC MODAL FORMULATION TEST
SUBTITLE = PROBLEM IV.3 - RESTART OF SOLUTION WITH NEW FLUID MODEL
ECHO = BOTH
SPC = 10
DISP = ALL
SUBCASE 2
    LABEL = MODES WITH FLUID INCLUDED
    METHOD = 60
    SPCF = ALL
BEGIN BULK
$
$ NEW FLUID MODEL
$
/       1       4
CFWEDGE 1       200     1       2       3       5       6       7
CFWEDGE 2       200     2       4       3       6       8       7
CFFREE  1       100     5               2       100     5
CFLSTR  1       101     104
CFLSTR  2       102     103     104
$
$ *** NOTE *** AT LEAST ONE GRID MUST BE ALTERED IN TO FORCE
$                  REEXECUTION OF PROPER MODULES
$
/       14
GRID    1               .0      .0      .0
$
$ PARAMETER TO SKIP RECOMPUTATION OF UNCHANGED STRUCTURE
$
PARAM   OLDSTR  -1
ENDDATA
```

FIGURE 12. PROBLEM IV.3 - FLUID MODEL CHANGE

7.1 AUTOMATED INPUT GENERATOR - MESHGEN

MESHGEN is a special purpose NASTRAN mesh/input generator for axisymmetric tank structures. It allows both the finite element idealization of the tank shell and its three-dimensional fluid contents for use with the NASTRAN hydroelastic analysis capability. The methodology employed requires minimal assumptions to maintain maximum generality for such fluid/structur_ geometries.

MESHGEN is implemented as a stand-alone utility that can be used to generate basic models, NASTRAN Bulk Data, and simple structural plots. An English language-based control structure, MESHLAN, has been chosen to simplify use understanding of the input generator processing. The syntax and verbal constructs of the language are oriented toward the structural analyst using terminology that is familiar. With little practice, many models can be generated without reference to a user's manual, thereby further reducing model preparation time and potential misunderstandings encountered with complex documentation.

Capabilities of MESHGEN

MESHGEN is capable of performing automatically a subset of mesh and input generation functions that will reduce input preparation time by an order of magnitude for large models. The specific tasks performed by MESHGEN are:

1. Fully automated finite element mesh generation for shells and solids of revolution, as well as a special three-dimensional truncated solid. This capability includes the facility to vary the mesh spacing.
2. Fully automated element definition utilizing any of the NASTRAN quadrilateral and triangular plate elements and fluid three-dimensional elements.
3. Complete user control over grid point and element numbering.

4. Automated generation of stringers with constant properties reinforcing a shell at regularly spaced circumferential or longitudinal stations.
5. Partially automated definition of permanent single-point constraints.
6. Automated generation of structure/fluid interaction data and fluid free surface data.
7. Simple structural plotting capability of both three-dimensional models and a two-dimensional pseudo-development.

These functions will eliminate all or most of the input preparation for the following classes of NASTRAN Bulk Data:

1. GRID cards
2. CONNECTION cards
3. PLØTEL cards for fluid free surfaces
4. CFFREE and CFLSTR cards

A feature is provided to eliminate the inconvenience of generating erroneous punched output by affording the user an opportunity to study the automatically generated model to determine its suitability before requesting punched output. The NASTRAN Bulk Data images are saved on a disk or drum file that may be accessed at a later time to punch a deck.

7.2 FUNCTIONAL DESCRIPTION OF MESHLAN

This section defines all of the MESHLAN statements that are used to generate finite element idealizations and NASTRAN Bulk Data for those geometries defined in Section III. The basic nomenclature used is described below.

Any word(s) capitalized and underlined are keywords and should appear exactly as shown in the description. However, only the first four letters of a keyword are required. Examples are:

MØDEL

ELEMENTS

GRAVITY

Any statement appearing in braces will be supplied by the user, as in:

{fluid level value}

{integer ID}

{value}

The use of square brackets denotes a set of options that may be selected by the user, i.e.:

$$\begin{bmatrix} \underline{\text{TANK}} \\ \underline{\text{FLUID}} \\ \underline{\text{GFLUID}} \\ \underline{\text{TFULL}} \end{bmatrix}$$

$$\begin{bmatrix} \underline{\text{R}} \\ \underline{\text{THETA}} \\ \underline{\text{Z}} \end{bmatrix}$$

Certain orderings of MESHLAN statements must be followed to avoid ambiguity. All statements are defined by a hierarchical level. Commands at the same level may be ordered in any manner, but subcommands <u>must</u> appear beneath their higher level command. A brief outline of the hierarchical structure is shown below (the numbers in ( ) refer to the number in the command description appearing later).

MØDEL (1)

GEØMETRY (2)

    SHAPE (3)
    BOUNDARY (4)

MESH (5)

    ØPRØPERTY (6)
    STEP or DIVIDE (7,8)

        ZPRØPERTY (9)
        SHELL or SØLID (10,11)

            NUMBER (12)
            INSYS (13)
            ØUTSYS (14)
            FIX (15)
            ELEMENTS (16)

                PRØPERTY (17)
                THICKNESS VARIES (18)

    STRINGERS (19)

        ALØNG (20)

GRAVITY (21)

PLØT (22)

PLT2 (23)

PLTHEAD (23a)

PUNCH (24)

FIND BØUNDARIES (25)

ENDM (26)

1. LEVEL 1 COMMAND MØDEL

SYNTAX:

MØDEL {model name} [, SAVE [,NEW]]

Defines the model identification. {model name} may be any string of 8 or less BCD characters starting with a letter. The SAVE option causes Bulk Data images to be written to the SAVE disk file for deferred IØ operations. (See Section V for a detailed description.) The first time a model is saved on a given disk file, NEW must be specified. NEW may not appear without SAVE.

EXAMPLES:

```
MØDEL TANK101
MØDEL SRU, SAVE, NEW
MØDEL SHUTTLE, SAVE
```

NOTE: Every case must begin with a MØDEL command.

2. LEVEL 1 COMMAND GEØMETRY

SYNTAX:

GEØMETRY

Defines the start of a sequence of geometry specification commands.

NOTE: This command must be present if a model is being generated.

3. LEVEL 2 COMMAND SHAPE

SYNTAX:

$$\text{SHAPE} = \begin{bmatrix} \text{SHELL ØF REVØLUTIØN} \\ \text{SØLID ØF REVØLUTIØN} \\ \text{TRUNCATED SØLID} \\ \text{CØNTAINED SØLID} \\ \text{CAPSHELL} \\ \text{CAPFLUID} \\ \text{CAPBØTH} \end{bmatrix} \text{ OR } \begin{bmatrix} \text{TANK} \\ \text{FLUID} \\ \text{GFLUID} \\ \text{TFULL} \\ \text{CAPS} \\ \text{CAPF} \\ \text{CAPB} \end{bmatrix}$$

Defines the basic geometric configuration of the model. (See Section III for a detailed description of the basic shapes.)

NOTE: This command may only appear as a subcommand of GEØMETRY.

4. LEVEL 2 COMMAND BØUNDARY

SYNTAX:

BØUNDARY = [FUNCTIØN {function ID} / TABLE {table ID} [INTERPØLATE]] [({fluid level value})]

Defines the boundary of the body of revolution either as an explicit function or a table. When the user specifies an explicit function, he may select any mesh divisions for his model. If TABLE is specified, and INTERPØLATE is absent, the values of Z given in the table will define the longitudinal mesh lines. If INTERPØLATE is present, then any divisions may be requested. The {fluid level value} is used to specify the axial position of the free surface of the fluid in the tank. This value is required to generate PLØTEL and CFFREE Bulk Data for any SHAPE involving a fluid, and must coincide with an axial station.

EXAMPLES:

```
BØUNDARY  =  TABLE 2
BØUNDARY  =  FUNCTIØN 12 (3.0)
BØUNDARY  =  TABLE 8 INTERPØLATE (5.5)
```

NOTE: This command may only appear as a subcommand of GEØMETRY.

A GRAVITY command (number 21) must be present if a fluid level is given.

TABLE without INTERPOLATE may not be used for SHAPE = GFLUID.

5. LEVEL 1 COMMAND <u>MESH</u>

SYNTAX:

<u>MESH</u> ({[G1] [,G2]})

Defines the initial grid point ID's for the model and signifies the start of the mesh definition commands. G1 is the initial ID for the shell portion of the model, G2 for the fluid. G1, G2 or both will be present as required by the <u>SHAPE</u>.

EXAMPLES:

MESH (101)
MESH (1,101)
MESH (,1001)

NOTE: A <u>MESH</u> command must be present if a model is being generated.

6. LEVEL 2 COMMAND <u>ØPRØPERTY</u>

SYNTAX:

<u>ØPRØPERTY</u> = {id}

Defines an overall property for the entire model.

7. LEVEL 2 COMMAND <u>STEP</u>

SYNTAX:

$$\underline{\text{STEP}} \begin{bmatrix} \underline{\text{R}} \\ \underline{\text{THETA}} \\ \underline{\text{Z}} \end{bmatrix} \underline{\text{FRØM}}\ \{\text{value 1}\}\ \underline{\text{TØ}}\ \{\text{value 2}\}\ \underline{\text{BY}}\ \{\text{increment}\}$$

Defines a zone of the model bounded in the specified direction by {value 1} and {value 2}. The integer {increment} defines the number of elements across the zone.

NOTE: STEP may appear only as a subcommand of MESH.

8. LEVEL 2 COMMAND DIVIDE

SYNTAX:

$$\text{DIVIDE} \begin{bmatrix} \underline{\text{R}} \\ \underline{\text{THETA}} \\ \underline{\text{Z}} \end{bmatrix} [\underline{\text{BY}}\ \{\text{increment}\}]$$

DIVIDE commands perform the same function as the STEP command, only they define divisions over the entire coordinate range specified on a boundary data card. (These data cards are defined at the end of this section.) In the THETA direction, a DIVIDE command assumes a range of $0° \leq \theta \leq 360°$. The {increment} is not required in the Z direction if a TABLE (no INTERPØLATE) boundary is specified.

NOTE: May appear only as a subcommand of MESH.

9. LEVEL 3 COMMAND ZPRØPERTY

SYNTAX:

ZPRØPERTY = {id}

Defines a zone element property identification for a particular STEP or DIVIDE command. The property ID throughout the zone will be taken as:

PID = ØPRØPERTY + ZPRØPERTY

NOTE: If ØPRØPERTY and ZPRØPERTY are both absent, the Property ID's are not punched. NASTRAN will assume a Property ID the same as the Element ID.

10. LEVEL 3 COMMAND SHELL

SYNTAX:

SHELL

Used only for TFULL or CAPBØTH SHAPES to allow separate attributes to be specified for the shell portion of the model.

11. LEVEL 3 COMMAND SØLID

SYNTAX:

SØLID

Used only for TFULL or CAPBØTH SHAPES to allow separate attributes to be specified for the fluid portion of the model.

12. LEVEL 4 CØMMAND NUMBER

SYNTAX:

NUMBER GRIDS BY {increment}, ELEMENTS BY {increment}

Defines the numbering increments desired for grid points and elements in the zone.

NOTE: Extreme care must be taken to assure that zone numberings do not overlap causing non-unique ID's.

13. LEVEL 4 COMMAND INSYS

SYNTAX:

INSYS = {id}

Defines an input coordinate system identification number (location) for all grid points in the zone.

14. LEVEL 4 COMMAND <u>ØUTSYS</u>

SYNTAX:

<u>ØUTSYS</u> = {id}

Defines an output coordinate system identification (displacements) for all generated grid points in the zone.

15. LEVEL 4 COMMAND <u>FIX</u>

SYNTAX:

<u>FIX</u> {dof code} <u>AT</u> [{coordinate list})

Defines permanent single-point constraints along grid lines within a zone. The {dof code} is the normal NASTRAN code of digits 1 - 6 with no embedded blanks. The {coordinate list} is any list of 25 or less values of coordinates along which the dof will be fixed.

EXAMPLE:

```
FIX 123456 AT (3.0)
FIX 246 AT (0.0, 3.0, 6.0)
```

NOTE: Permanent constraints may <u>not</u> be applied to fluid points.

16. LEVEL 4 COMMAND <u>ELEMENTS</u>

SYNTAX:

<u>ELEMENTS</u> = {element type}, {id}

Defines the element types desired for the zone. The types must be consistent with the <u>SHAPE</u> of the model. {id} is the initial element ID number. Legal element types for each shape are summarized below.

Shape	Elements
TANK	QDMEM, QDMEM1, QDMEM2, QDPLT, QUAD1, QUAD2, SHEAR, TWIST, TRMEM, TRBSC, TRPLT, TRIA1, TRIA2
FLUID	FHEX1, FHEX2
GFLUID	FHEX1, FHEX2
CAPS	TRMEM, TRBSC, TRPLT, TRIA1, TRIA2
CAPF	FWEDGE, FHEX1, FHEX2

NOTE: ELEMENTS commands may only appear in Z zone definitions.

17. LEVEL 5 COMMAND PRØPERTY

SYNTAX:

PRØPERTY = {id}[,{alpha}]

Defines element properties. The final property ID will be:

PID = ØPRØPERTY + ZPRØPERTY + PRØPERTY

{alpha} is the material orientation angle for relative plate elements.

18. LEVEL 5 COMMAND THICKNESS

SYNTAX:

THICKNESS VARIES

Used to direct the program to use different Property ID's at each coordinate station to allow for uniform thickness variations in plate elements.

19. LEVEL 3 COMMAND STRINGER

SYNTAX:

$$\text{STRINGER} = \begin{bmatrix} \text{BAR} \\ \text{RØD} \end{bmatrix} \{\text{property id}\}, \{\text{id 1}\}, \{\text{id 2}\}$$

Defines STRINGER (RØDS or BAR) that stiffen the shell. {property id} must be 0 for BARs and a BARØR card input by user into the NASTRAN Bulk Data deck. {id 1} and {ii 2} are the initial element ID's in the THETA and Z directions, respectively. Both numbers must be present.

EXAMPLES:

STRINGER = BAR 0, 101, 201
STRINGER = RØD 100, 1001, 2001

NOTE: Only constant property stringers are allowed. It is possible to vary stringer properties by manually punching the remaining fields on the CBAR cards.

20. LEVEL 4 COMMAND <u>ALØNG</u>

SYNTAX:

$$\underline{\text{ALØNG}} \begin{bmatrix} \underline{\text{THETA}} \\ \underline{\text{Z}} \end{bmatrix} \underline{\text{AT}} \text{ (\{list of } \begin{bmatrix} \underline{\text{Z}} \\ \underline{\text{THETA}} \end{bmatrix} \text{ coordinate values\})}$$

Defines the mesh lines along which the stringers run. The {list of coordinate values} must correspond to grid lines. The stringers will extend to the boundaries of the mesh and will be spaced as defined by the list.

EXAMPLES:

ALØNG Z AT (90.0, 30.0)
ALØNG THETA AT (1.0, 0.0)

21. LEVEL 1 COMMAND <u>GRAVITY</u>

SYNTAX:

<u>GRAVITY</u> = {id}

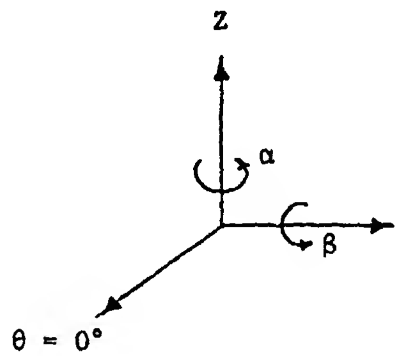
Defines a GRAV ID to be used on free surface (CFFREE) and fluid/structure (CFLSTR) Bulk Data cards.

22. LEVEL 1 COMMAND <u>PLØT</u>

SYNTAX:

<u>PLØT</u> [{α}, {β}][,<u>NØNUM</u>]

Requests three-dimensional plot of the current model. {α} and {β} are angles to change the plot orientation. The natural view angle is looking toward the structure at θ = 0°, α controls rotations about the Z axis, and β the inclination angle as shown below:



If <u>NØNUM</u> is elected, no grid ID numbers will be printed.

NOTES: Be sure appropriate plot tape is mounted. The order of rotations is [illegible]llowed by β. If α and β are absent, they are taken as 0.0.

23. LEVEL 1 COMMAND <u>PLT2</u>

SYNTAX:

<u>PLT2</u> [,<u>NØNUM</u>]

Generates a two-dimensional pseudo-developed plot of the current model. NØNUM is the same as in <u>PLØT</u>. PLT2 may not be used except for shell of revolution and shell cap models.

-- ADDENDUM --

23a. LEVEL 1 COMMAND PLTHEAD

SYNTAX:

PLTHEAD NAME,ACC'T,JØBNAME,BIN#

Used to generate SC4020 plot identification frame. The input values are: programmer name, account number, job name, and bin number. All values must be 8 or less BCD characters beginning with a letter.

NOTE: This command is required to generate plots at MSFC on the IBM 360/65.

24. LEVEL 1 COMMAND PUNCH

SYNTAX:

PUNCH [{model name}]

Causes the Bulk Data images to be punched on cards. Punching the current model does not require {model name}. It is required to retrieve a model from the SAVE file.

25. LEVEL 1 COMMAND FIND BØUNDARIES

SYNTAX:

FIND BOUNDARIES {name 1}, {name 2}

This command causes fluid/structure interface data (CFLSTR) to be generated when the structure and fluid models have been generated separately. {name 1} and {name 2} are, respectively, the model names of the STRUCTURE and FLUID in that order. Each must exist on the SAVE file. Neither model can be of the TFULL or CAPBØTH types.

26. LEVEL 1 COMMAND ENDM

SYNTAX:

ENDM

Ends the model case.

NOTE: Must be present for every case run, whether for model generation or IØ operations.

Specifying the Boundary Function

The boundary function defining the shell or solid of revolution may be specified either as a table of (r,z) values, or as the incomplete conic:

$$a_1z^2 + a_2z + a_3r^2 + a_4r = a_5^2 + a_6$$

The input format for this function definition is free format, i.e., the individual values on the card may be placed in any position on the card as long as they are separated by a comma or blanks and maintain the order defined below (no data may appear beyond column 72).

1. Data Delimiter

    $DATA

2. Functional Definition

Input No.	Contents
1	FUNCTIØN
2	ID
3-4	z_1, z_2 closed interval defining boundary
5	α used for truncated solid
6-11	a_i coefficients of conic

3. Tabular Definition

Input No.	Contents
1	TABLE
2	ID
3-4	z_1, z_2
5	α
6	NPT number of points in table
7-8 9-10 11-12 etc.	(r_i, z_i) function definition (as many cards as necessary). The values z_1 and z_2 <u>must</u> correspond to the exact limits of the structure.

Control Sequences

The commands required for a given case are determined by the operations being performed. These operations are model generation or IØ. The allowable processes are shown below, indicating the required primary commands.

1. Model Generation

   MØDEL
   GEØMETRY
   ⋮
   MESH
   ⋮
   PLØT
   PUNCH   optional
   ENDM

2. Punching Bulk Data from the SAVE File

   MØDEL
   PUNCH {model name}
   ENDM

3. Generation of CFLSTR cards when the shell and fluid models have been generated separately and saved.

   MØDEL
   GRAVITY
   FIND BØUNDARIES {shell name}, {fluid name}
   PUNCH
   ENDM

File Definitions

MESHGEN requires three or four scratch files, depending on the operation being performed, and two output files. The FØRTRAN unit numbers have been assigned as shown below, but may be changed by updating subroutine MESHBD.

File Always Required:

```
//FT15F001 DD UNIT=SYSDA, SPACE=(TRK,(1,1)),
//          DCB=(RECFM=FB,LRECL=80,BLKSIZE=12960)

//FT19F001  same as above

//FT18F001 DD UNIT=SYSDA, SPACE=(TRK,(1,1)),
//          DCB=(RECFM=UBS,LRECL=84,BLKSIZE=13024)
```

Required to Perform SAVE:

```
//FT17F001 DD DSN=anyname, VØL=SER=id,
//      DISP=(,CATLG), SPACE=(TRK,(a,b)),
//      DCB=(RECFM=VBS,LRECL=84,BLKSIZE=13024),UNIT=3330
```

a and b are determined by the amount of data to be saved. For each track allocated, 150 Bulk Data images may be saved.

Required to Perform PLOTS:

```
//FT14F001 DD UNIT=SYSDA, SPACE=(TRK,(1,1)),
//          DCB=(RECFM=VBS,LRECL=84,BLKSIZE=13024)
```

and the SC4020 plot output unit definition such as

```
//FT16F001 DD UNIT=(TAPE7),LABEL=(1,BLP),
//      DISP=(NEW,KEEP),DCB=(RECFM=F,LRECL=1152,
//      BLKSIZE=1152),VØL=(PRIVATE,,SER=SC4020)
```

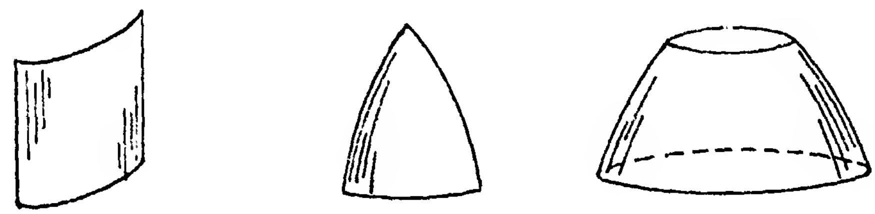
The SC4020 file is system dependent and varies from installation to installation.

7.3 MESHGEN GEOMETRY TYPES

MESHGEN can generate models for seven basic geometric configurations. They are:

1. Shell of Revolution

A shell is defined by rotating the function $r=f(z)$, defined on the closed interval $[a,b]$, through an angle of θ degrees about the z axis. The resultant surface may be open, closed in θ (i.e., $\theta = 360°$), closed in z (i.e., $f(a) \equiv 0$ or $f(b) \equiv 0$) or closed in θ and z. Sample shapes are:

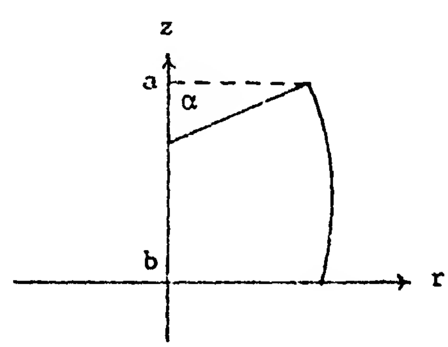


2. Solid of Revolution

A solid is generated by the same procedure as the shell.

3. Truncated Solid of Revolution

This figure is defined as an ordinary shell of revolution, but has an additional parameter, α. This is the angle the top surface of the solid makes with the line $z=a$, i.e.,



This model is used to define fluids with tilted surfaces.

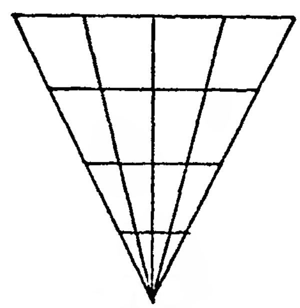
4. <u>Contained Solid</u>

This option allows a tank (shell of revolution) and its fluid contents (solid of revolution) to be generated in one pass.

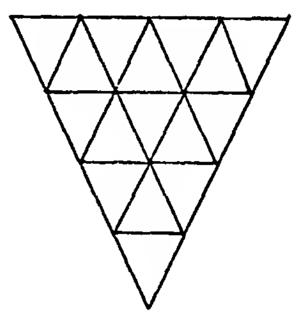
5. <u>Shell Cap</u>

The shell cap is a two-dimensional model that corresponds to the shell of revolution. The only difference is that the elements are generated in an isoparametric manner. In particular, the axial (z) coordinate values are not defined in equal increments, but the actual arc length of the generating function is divided equally. Depending on the function, this may allow better geometry of the finite elements. For example:

Shell of Revolution Model:



Shell Cap Model:

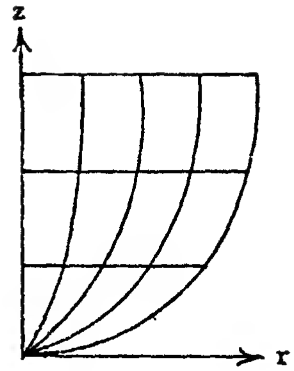


Note that a shell cap can <u>NOT</u> be closed in θ and <u>MUST</u> be closed in z.

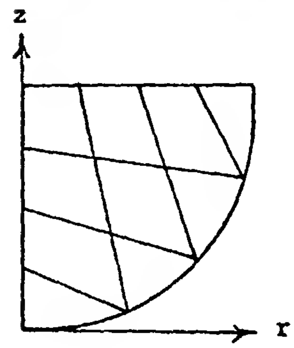
6. <u>Solid Cap</u>

The solid cap is analogous to a three-dimensional shell cap. It also provides for better element behavior in certain cases. This model has an isoparametric style cross-section and equal increments in θ. For example:

Solid of Revolution:



Solid Cap:



The solid cap MUST be closed in z.

7. Cap Both

This option allows a tank and fluid model to be generated in one step using the Solid Cap and Shell Cap methods.

These seven capabilities allow for well-behaved finite element models of tank/fluid systems.

7.4 DEMONSTRATION PROBLEMS AND USER'S GUIDE

The following section is a collection of sample problems demonstrating the MESHGEN capabilities. There are both simple and more complex examples to help the user become familiar with this powerful tool. The problems are numbered to correspond to the seven geometric configurations that may be modeled. In addition, the last problem is a deck that generated a model actually used to solve the SRI tank problem.

SAMPLE PROBLEM 1.1

1.1.1 Description:

Model a 90° segment of a right circular cylinder, with 5 inch radius, on the interval z=[3.,0.] . Assume homogenious properties and use QDMEM elements.

1.1.2 MESHLAN Program:

```
MØDEL TEST1.1
GEØMETRY
    SHAPE = TANK
    BØUNDARY = FUNCTION 1
MESH(1)
ØPRØP = 100
DIVIDE Z BY 3
    NUMBER GRIDS BY 5,ELEMENTS BY 4
    ELEMENTS = QDMEM,1
STEP THETA FRØM 0.0 TØ 90.0 BY 4
    NUMBER GRIDS BY 1,ELEMENTS BY 1
PLØT -45.0,20.0
PLT2
ENDM
$DATA
FUNCTION 1,3.,0.,0.,0.,0.,0.,1.,0.,5.
```

NOTES: a. The DIVIDE Z BY 3 command means that the range of Z specified by the FUNCTION card will be used.
b. A three dimensional and two dimensional pseudo-developed plot will be made.

1.1.3 Model:

Figures 1.1 and 1.2 are the MESHGEN plots generated by this problem.

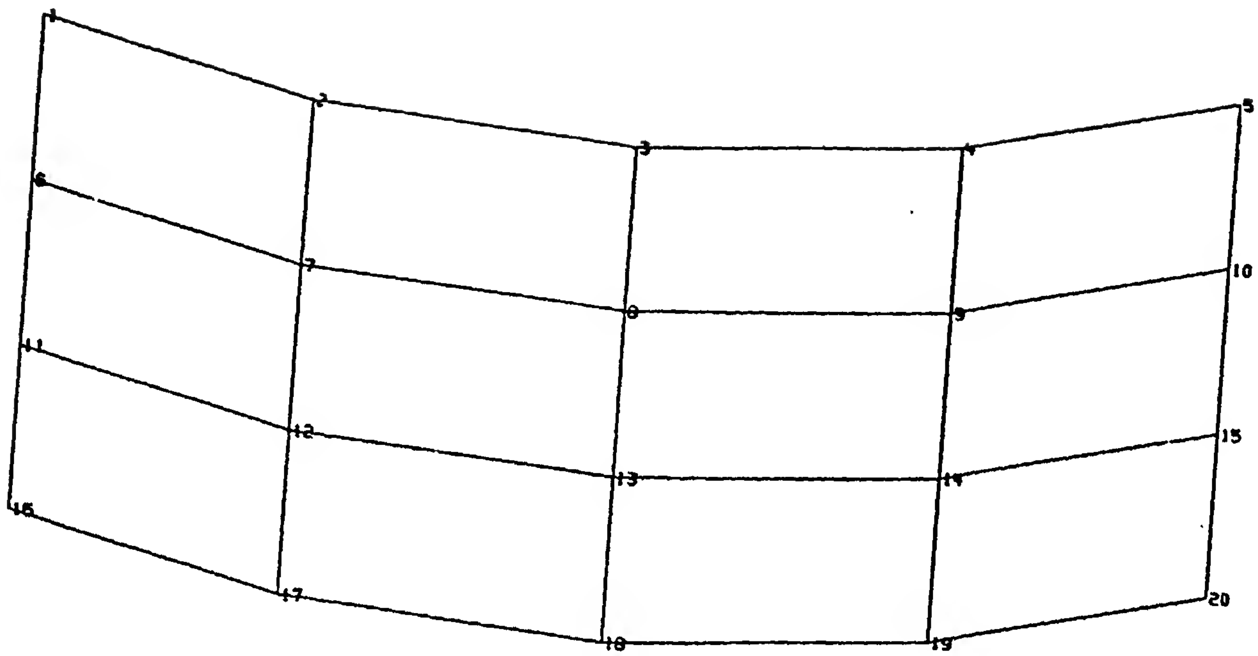


FIGURE 1.1

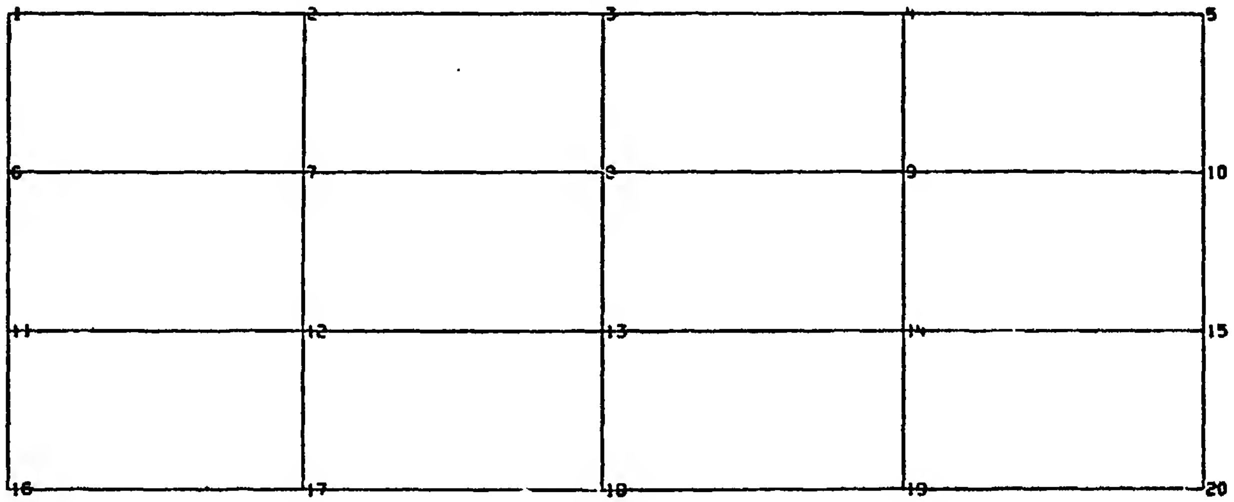


FIGURE 1.2

SAMPLE PROBLEM 1.2

1.2.1 Description:

Generate a model of the upper hemisphere of the sphere $z^2-6z+r^2 = 0$ on the interval z=[3.,6.]. Model the structure with QUAD2 elements assuming a uniform axial variation in shell thickness. Also, assume that output displacements are requested in another coordinate system, CID = 200.

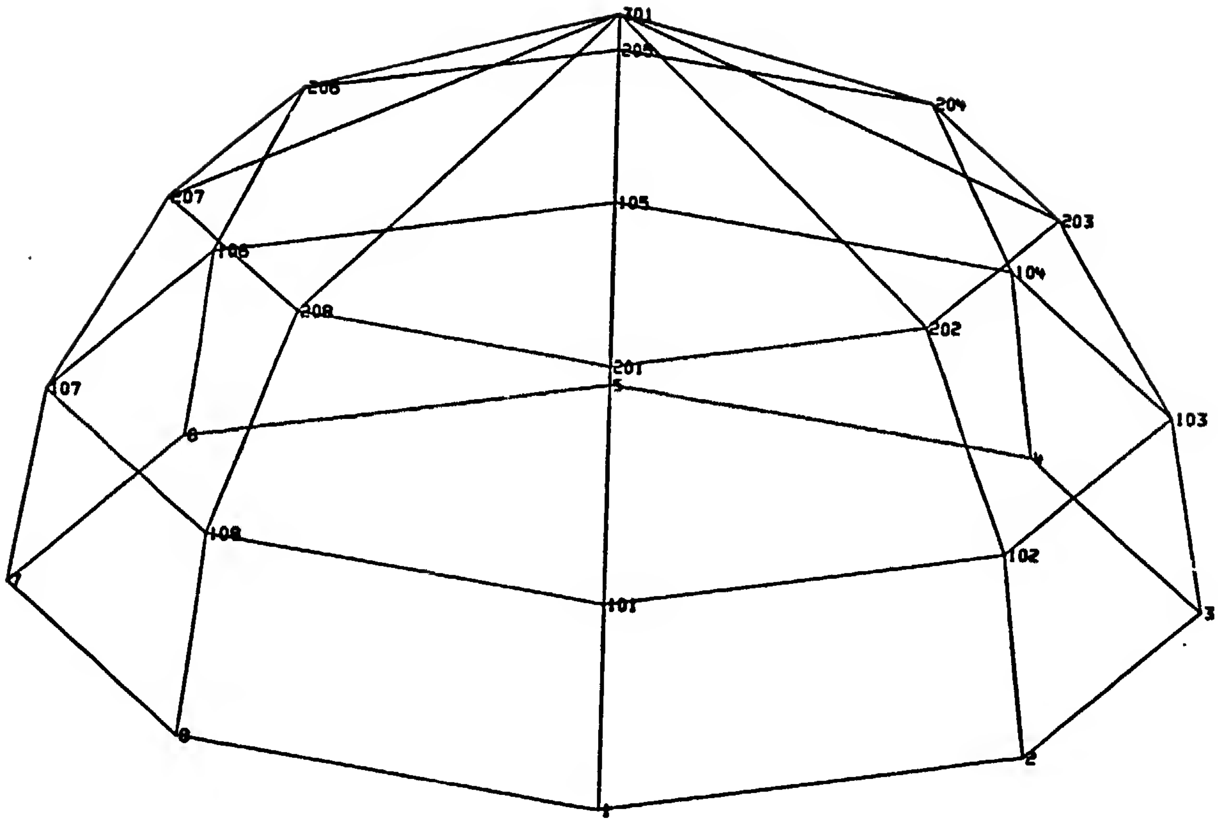
1.2.2 MESHLAN Program:

```
MØDEL TEST1.2
GEØMETRY
    SHAPE = SHELL ØF REVØLUTIØN
    BØUNDARY = FUNCTIØN 2
MESH(1)
ØPRØP = 100
DIVIDE Z BY 3
    ØUTSYS = 200
    NUMBER GRIDS BY 100,ELEMENTS BY 100
    ELEMENTS = QUAD2,1
        THICKNESS VARIES
DIVIDE THETA BY 8
    NUMBER GRIDS BY 1,ELEMENTS BY 1
PLOT 0.,20.
PLT2
ENDM
$DATA
FUNCTION 2,3.,6.,0.,1.,-6.,1.,0.,0.,0.
```

1.2.3 Model.

The MESHGEN plots for this model are shown in figures 1.3 and 1.4.

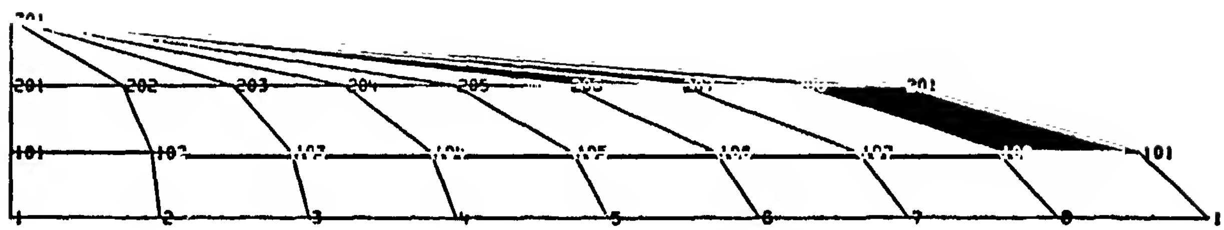
76224 NAUA164M
0000 0001



3D VIEW ANGLES 0.0 20.0 OF TEST1.2

FIGURE 1.3

78224 NAUA184M
0000 0002



2D VIEW ANGLES 0.0 0.0 OF TEST1.2

FIGURE 1.4

SAMPLE PROBLEM 1.3

1.3.1 Description:

Model a 90° segment of a right circular cylinder r=4 with homogeneous properties. In addition, fix all degrees of freedom at z=2 and fix dof 246 at θ=0° and 90°. Use TRIA1 elements.

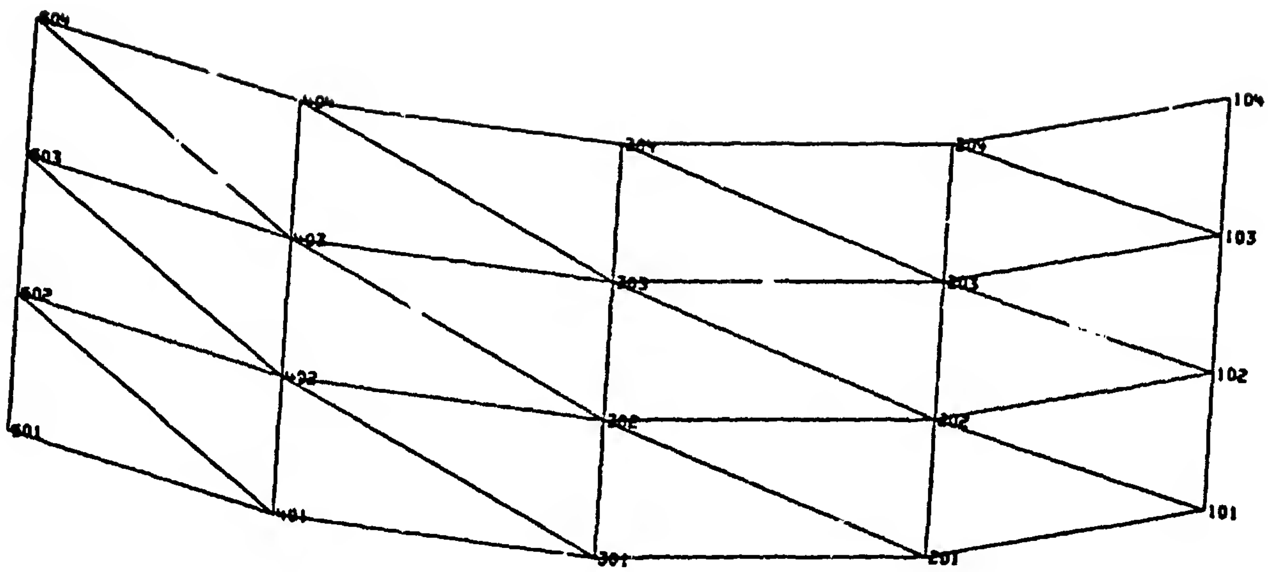
1.3.2 MESHLAN Program:

```
MØDEL TEST1.3
GEØMETRY
    SHAPE = TANK
    BØUNDARY = TABLE 48 INTERPØLATE
MESH(101)
ØPRØP = 100
DIVIDE Z BY 3
    NUMBER GRIDS BY 1,ELEMENTS BY 8
        ELEMENTS = TRIA1,1
    FIX 123456 AT(2.0)
STEP THETA FROM 90.0 TO 0.0 BY 4
    NUMBER GRIDS BY 100,ELEMENTS BY 1
    FIX 246 AT (0.0,90.0)
PLØT -45.,20.
PLT2
ENDM
$DATA
TABLE 48,0.,2.,0.,2,4.,0.,4.,2.
```

1.3.3 Model:

Figures 1.5 and 1.6 are MESHGEN plots of this model.

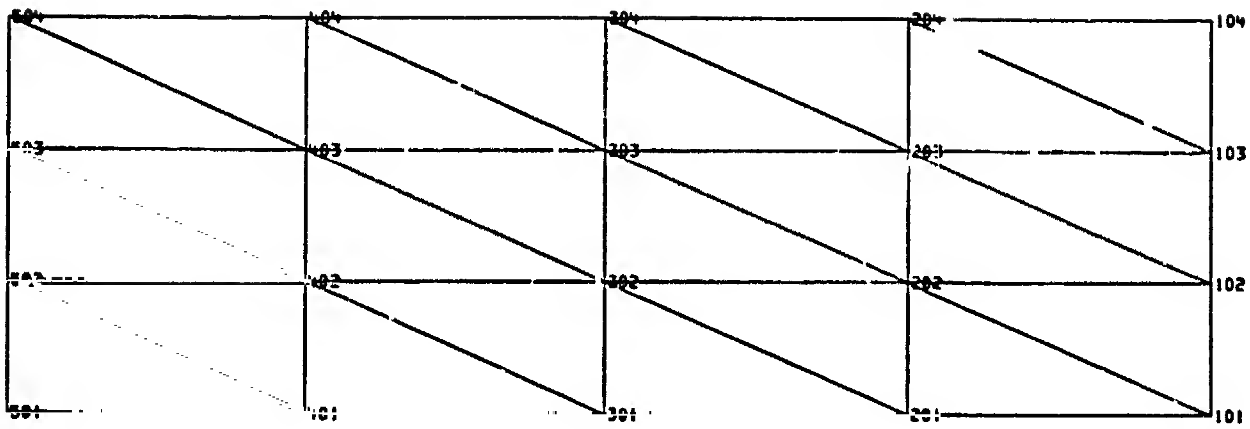
76224 NAUA164M
0000 0003



3D VIEW ANGLES -45.0 20.0 OF TEST1.3

FIGURE 1.5

78224 NAUA1844
0000 00'.



2D VIEW ANGLES 0.0 0.0 OF TEST1.3

FIGURE 1.6

SAMPLE PROBLEM 1.4

1.4.1 Description:

Model the 360° surface generated by the parabola $25z=r^2$ using TRIA1 elements and assuming homogeneous properties.

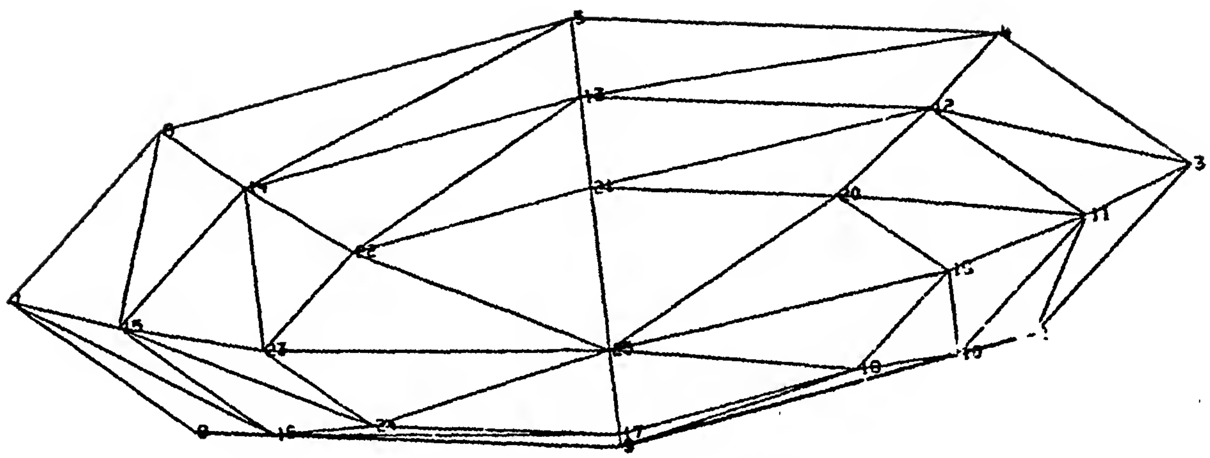
1.4.2 MESHLAN Program:

```
MØDEL TEST1.4
GEØMETRY
    SHAPE = TANK
    BØUNDARY = FUNCTIØN 3
MESH(1)
ØPRØP = 100
DIVIDE Z BY 3
    NUMBER GRIDS BY 8,ELEMENTS BY 1
        ELEMENTS = TRIA1,1
DIVIDE THETA BY 8
    NUMBER GRIDS BY 1,ELEMENTS BY 3
PLØT 0.,20.
PLT2
ENDM
$DATA
FUNCTIØN 3,1.,0.,0.,0.,1.,-4.,0.,0.,0.
```

1.4.3 Model:

The model is shown in Figures 1.7 and 1.8.

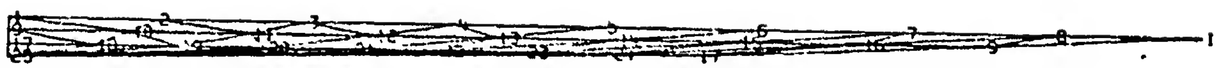
76224 NAUA164M 0000 0005



3D VIEW ANGLES 0.0 20.0 OF TEST1.4

FIGURE 1.7

76224 NAUAI64M
0000 0006



20 VIEW ANGLES 0.0 0.0 OF TESTI.4

FIGUIE 1.8

SAMPLE PROBLEM 1.5

1.5.1 Description:

Model a 120° segment of a right circular cylinder r=5 on z=[5.,3.] with mesh refinements in both the radial and axial coordinate directions. Properties vary linearly in axial direction and the shell is stiffened by longerons at z=5 and θ=0°, 90° and 120°. Use QDPLT elements.

1.5.2 MESHLAN Program

```
MØDEL TEST1.5
GEØMETRY
    SHAPE = SHELL ØF REVØLUTIØN
    BØUNDARY = FUNCTIØN 8
MESH(1)
STEP Z FRØM 5.0 TO 3.0 BY 2
    NUMBER GRIDS BY 7,ELEMENTS BY 50
        ELEMENTS = QDPLT,1
            THICKNESS VARIES
STEP Z FROM 3.0 TO 1.0 BY 3
    NUMBER GRIDS BY 7,ELEMENTS BY 50
        ELEMENTS = QUAD2,151
            PROPERTY = 1000,15.0
STEP THETA FROM 0.0 TO 90.0 BY 3
    NUMBER GRIDS BY 1,ELEMENTS BY 1
STRINGERS=BAR 0,10001,20001
    ALØNG Z AT (0.0,90.0,120.)
    ALØNG THETA AT (5.0)
PLØT -60.,20.
ENDM
$DATA
FUNCTION 8,5.,1.,0.,0.,0.,0.,1.,0.,5.
```

1.5.3 Model:

A three-dimensional MESHGEN plot of the model is shown in Figure 1.9.

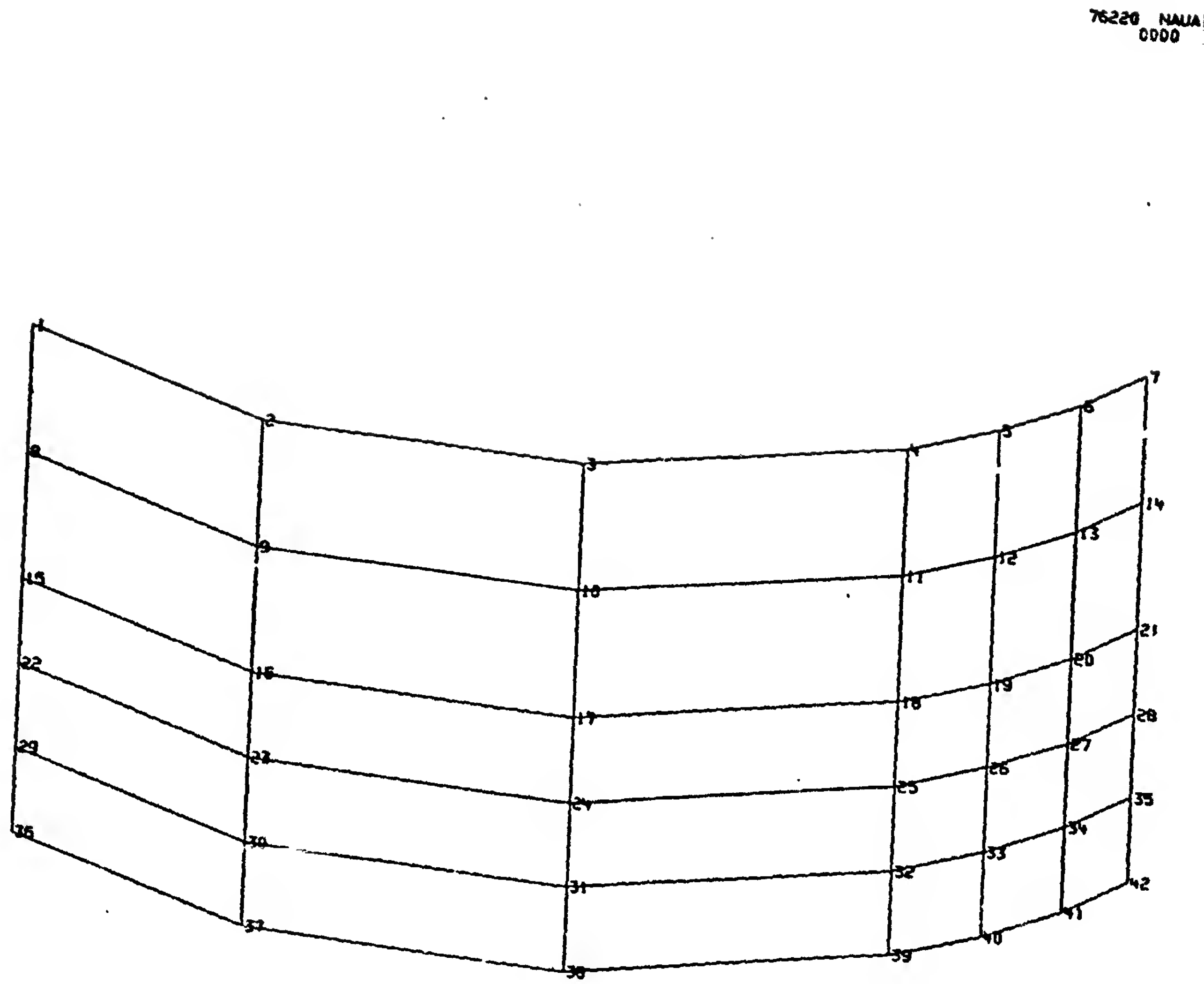


FIGURE 1.9

SAMPLE PROBLEM 1.6

1.6.1 Description:

The problem solved in 1.5 is re-executed to illustrate the capability of generating overlapping elements of different types in different axial zones.

1.6.2 MESHLAN Program:

```
MØDEL TEST1.6
GEØMETRY
    SHAPE = SHELL ØF REVØLUTIØN
    BØUNDARY = FUNCTIØN 8
MESH(1)
ØPRØP = 100
STEP Z FRØM 5.0 TØ 3.0 BY 2
    ZPRØP = 10
    NUMBER GRIDS BY 7,ELEMENTS BY 50
        ELEMENTS = QDPLT,1
            THICKNESS VARIES
        ELEMENTS = SHEAR,1001
            PRØPERTY = 50
STEP Z FROM 3.0 TØ 1.0 BY 3
    ZPRØP = 20
    NUMBER GRIDS BY 7,ELEMENTS BY 50
        ELEMENTS = QUAD2,151
            PRØPERTY = 1000,15.0
        ELEMENTS = TWIST,1151
            PRØPERTY = 800
        ELEMENTS = QDMEM2,2151
            PRØPERTY = 655,25.
                THICKNESS VARIES
STEP THETA FRØM 0.0 TØ 90.0 BY 3
    NUMBER GRIDS BY 1,ELEMENTS BY 1
STEP THETA FRØM 90.0 TØ 120.0 BY 3
    NUMBER GRIDS BY 1,ELEMENTS BY 1
STRINGERS=BAR 0,10001,20001
    ALØNG Z AT (0.0,90.0,120.)
    ALØNG THETA AT (5.0)
ENDM
```

1.6.3 Model:

The model resulting, with respect to grid point and element configuration, is the same as 1.5.

SAMPLE PROBLEM 1.7

1.7.1 Description:

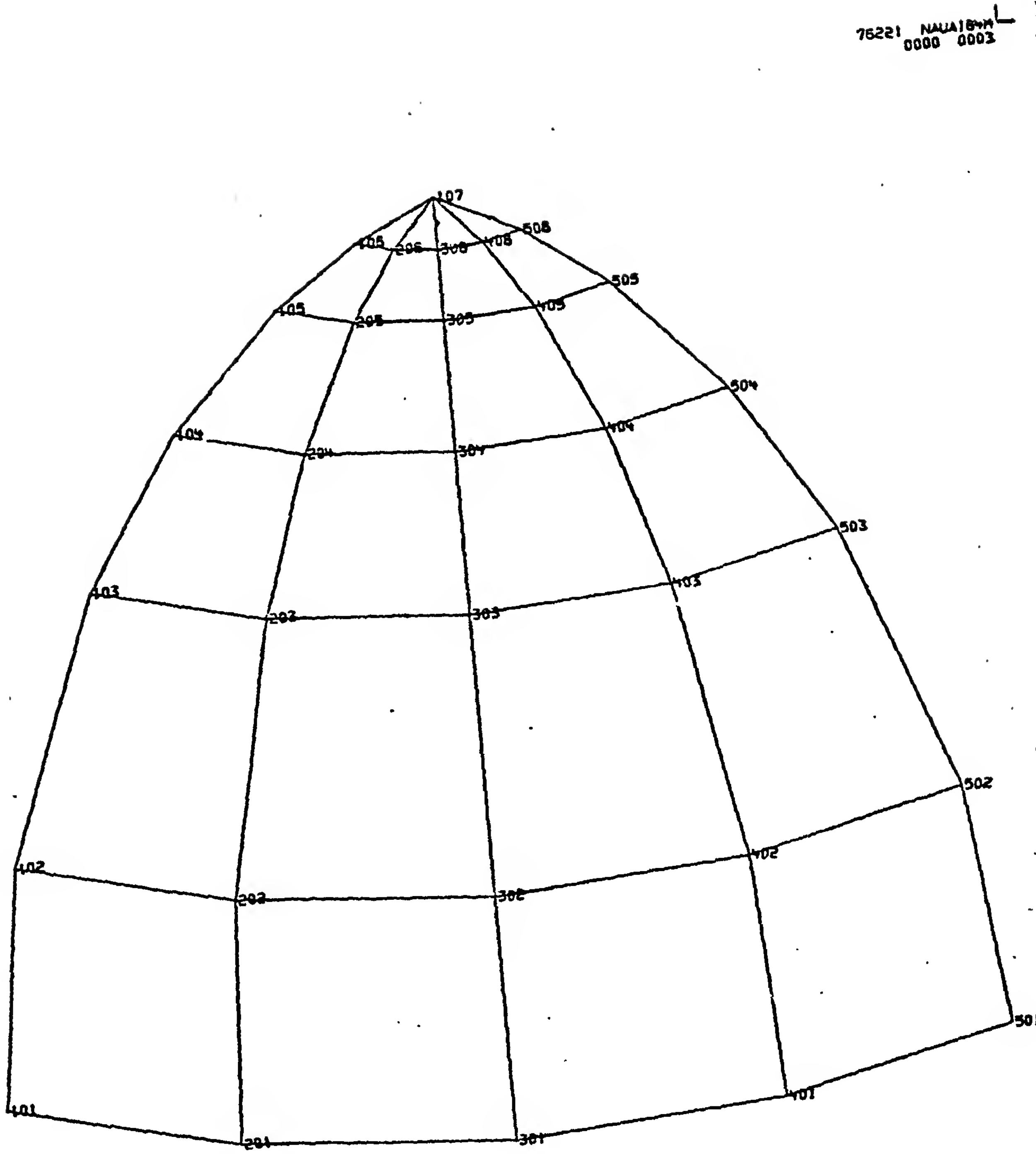
Model of a quadrant of a hemisphere where the axial stations are explicitly defined by the user.

1.7.2 MESHLAN Program:

```
MØDEL TEST1.7
GEØMETRY
    SHAPE = TANK
    BØUNDARY = TABLE 88
MESH(101)
DIVIDE Z
    NUMBER GRIDS BY 1,ELEMENTS BY 1
        ELEMENTS = QDMEM2,1
STEP THETA FROM 0.0 TO 90.0 BY 4
    NUMBER GRIDS BY 100,ELEMENTS BY 6
PLØT -45.,20.
PLT2
ENDM
$DATA
TABLE 88,6.,12.,0.,7,6.,6.,5.657,8.,4.472,10.,3.317,
      11.,2.,11.657,1.,11.916,0.,12.
```

1.7.3 Model:

MESHGEN plots are shown in Figures 1.10 and 1.11.



76221 NAUA184M 0000 0003
107
108
206
306
408
508
105
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505
104
204
304
404
504
103
203
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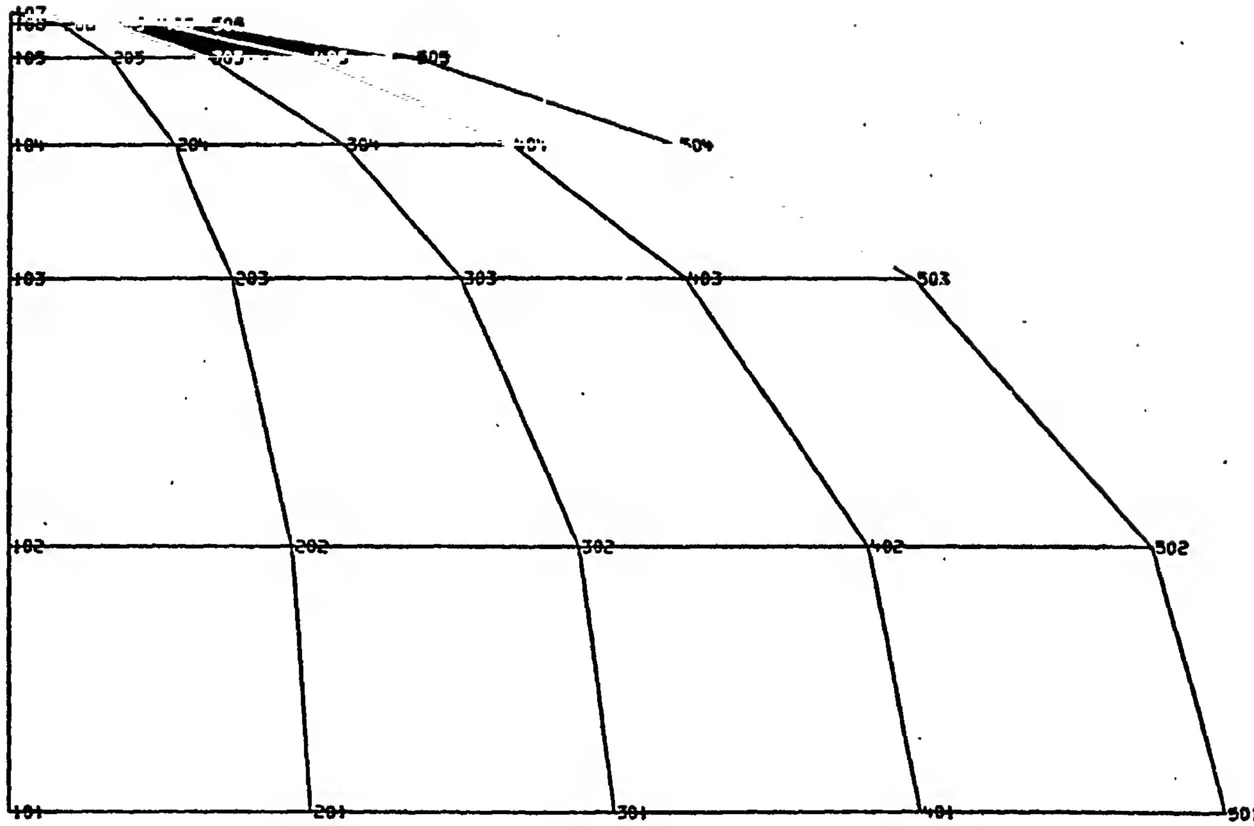
403
503
102
202
302
402
502
101
201
301
401
501

FIGURE 1.10


101
201
301
401
501
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202
302
402
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103
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504
105
205
505

FIGURE 1.11

SA ?LE PROBLEM 1.8

1.8.1 Description:

A model is generated for a 90° segment of a complex tank composed of three distinct sections. These are executed as three cases which will be merged to generate the final Bulk Data deck.

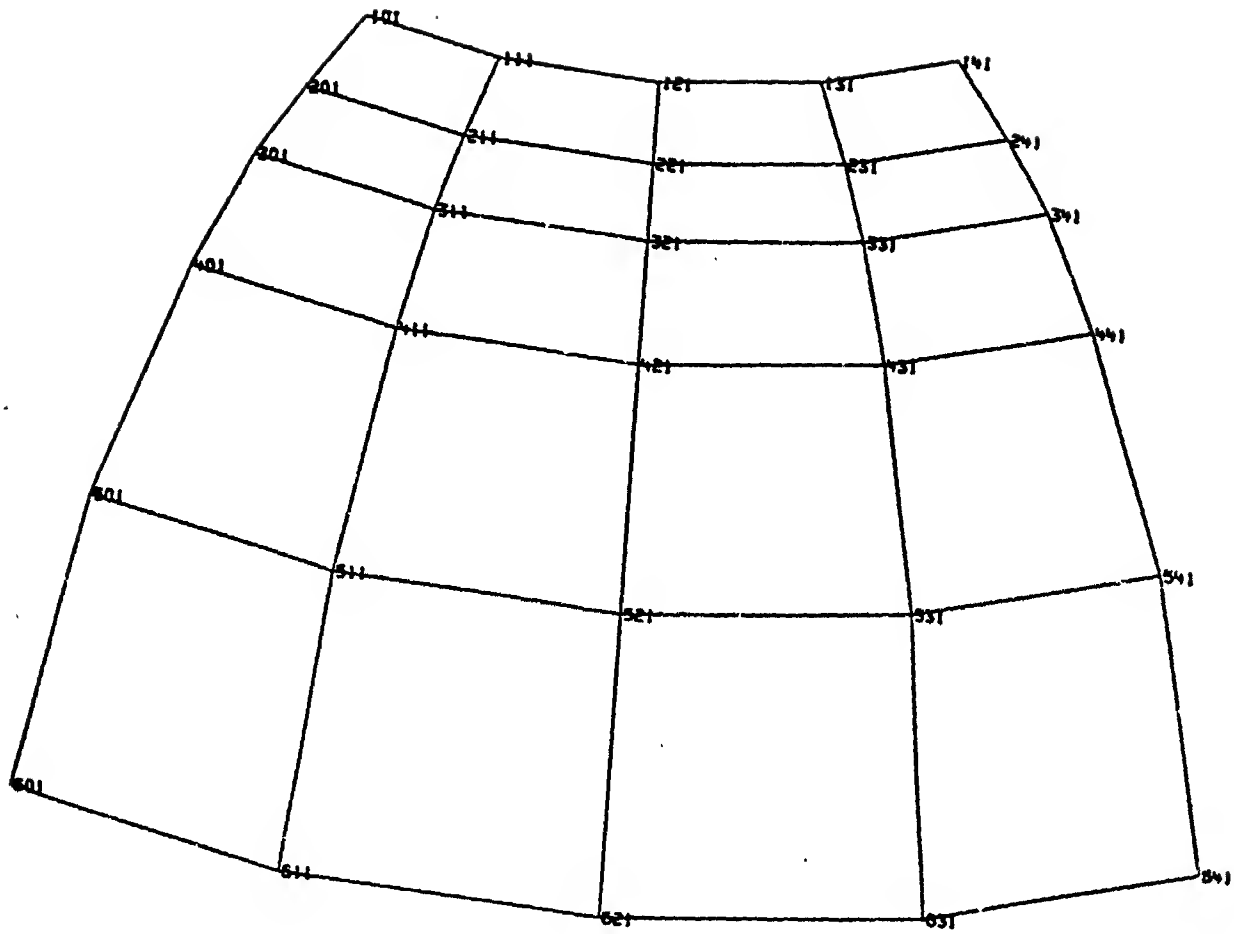
1.8.2 MESHLAN Program:

```
MØDEL TEST1.8A
GEØMETRY
    SHAPE = TANK
    BØUNDARY = TABLE 6
MESH(101)
DIVIDE Z
    FIX 123456 AT (15.)
    NUMBER GRIDS BY 100,ELEMENTS BY 10
    ELEMENTS = QUAD2,1
        PRØPERTY = 100
            THICKNESS VARIES
STEP THETA FROM 0.0 TØ 90.0 BY 4
    FIX 246 AT (0.0,90.)
    NUMBER GRIDS BY 10,ELEMENTS BY 1
STRINGER = BAR 0,1001,2001
    ALØNG A AT (45.0)
    ALØNG THETA AT (10.0)
PLØT -45.0,20.
ENDM

MØDEL TEST1.8B
GEØMETRY
    SHAPE = TANK
    BØUNDARY = FUNCTIØN 12
MESH(601)
ØPRØP = 100
DIVIDE Z BY 3
    NUMBER GRIDS BY 100,ELEMENTS BY 10
    ELEMENTS = QUAD2,51
STEP THETA FRØM 0.0 TØ 90.0 BY 4
    FIX 246 AT (0.0,90.)
    NUMBER GRIDS BY 10,ELEMENTS BY 1
STRINGER = BAR 0,1101,2101
    ALØNG Z AT (22.5,67.5)
    ALØNG THETA AT (3.0)
ENDM

MØDEL TEST1.8C
GEØMETRY
    SHAPE = TANK
    BØUNDARY = TABLE 73 INTERPØLATE
MESH(901)
ØPRØP = 100
```

```
STEP Z FRØM 3.0 TØ 0.0 BY 3
    NUMBER GRIDS BY 100,ELEMENTS BY 10
    ELEMENTS = QUAD2,81
        THICKNESS VARIES
STEP THETA FRØM 0.0 TØ 90.0 BY 4
    FIX 246 AT (0.0,90.)
    NUMBER GRIDS BY 10,ELEMENTS BY 1
PLØT -45.,20.
PLT2
ENDM
$DATA
TABLE 6,15.,10.,0.0,6,6.,10.,5.4,12.,4.55,13.5,4.0,
      14.2,3.55,14.6,3.0,15.0
FUNCTIØN 12,10.0,3.0,0.0,0.,0.,0.,1.,0.,6.
TABLE 73,3.0,0.0,0.0,7,0.0,0.0,1.0,0.3,2.0,.7,3.0,
      1.1,4.0,1.6,5.0,2.25,6.0,3.0
```

1.8.3 Model:

Figure 1.12 shows the boundary definition of the tank structure. Three-dimensional plots of the A and C portion, and a two-dimensional plot of the C portion are shown in Figures 1.13 - 1.15.


101
111
121
131
141
201
211
221
231
241
301
311
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341
401
411
421
431
441
501
511
521
531
541
601
611
621
631
641

FIGURE 1.13

76221 NAUA184M
0000 0005

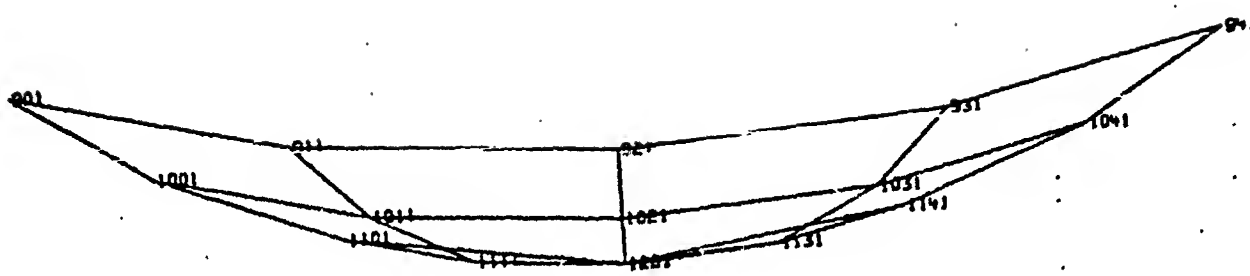


FIGURE 1.14

76221 NAUA184M
0000 0006

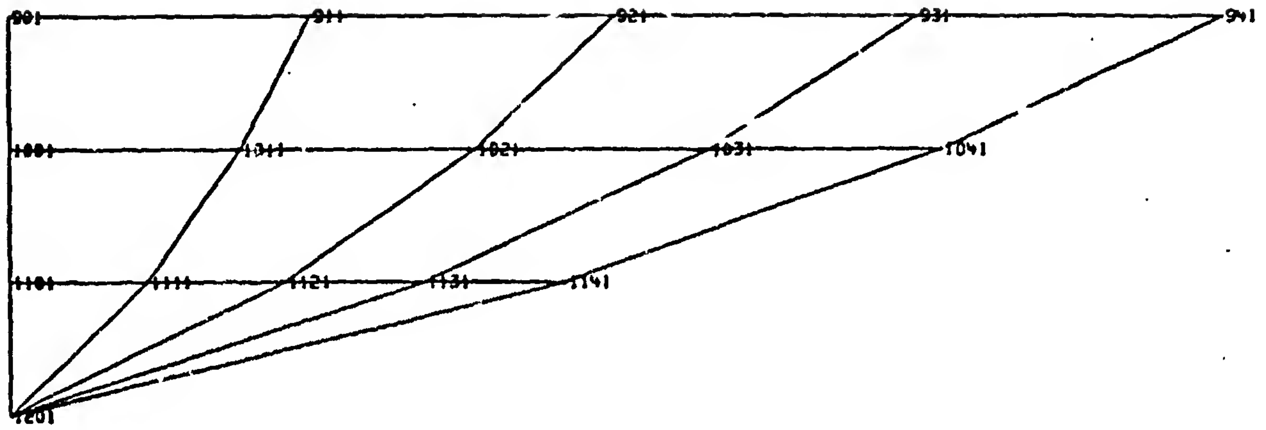


FIGURE 1.15

SAMPLE PROBLEM 2.1

2.1.1 Description:

Model the three-dimensional solid segment of the right circular cylinder defined in 1.1 using FHEX2 elements.

2.1.2 MESHLAN Program:

```
MØDEL TEST2.1
GEØMETRY
    SHAPE = FLUID
    BØUNDARY = FUNCTIØN 1(3.0)
GRAV = 100
MESH(,1)
ØPRØP = 200
DIVIDE Z BY 3
    NUMBER GRIDS BY 5, ELEMENTS BY 4
        ELEMENTS = FHEX2,1
STEP THETA FROM 0.0 TØ 90.0 BY 4
    NUMBER GRIDS BY 1, ELEMENTS BY 1
DIVIDE R BY 3
    NUMBER GRIDS BY 100, ELEMENTS BY 100
PLØT -40.,20.0,NØNUM
ENDM
$DATA
FUNCTION 1,3.,0.,0.,0.,0.,0.,1.,0.,5.
```

NOTES: a. A free surface value (3.0) and GRAV command are given in order to generate PLØTEL and CFFREE Bulk Data.

b. NØNUM is specified on the PLØT card to omit grid point numbering.

2.1.3 Model:

Figure 2.1 shows the three-dimensional MESHGEN plot for this solid.

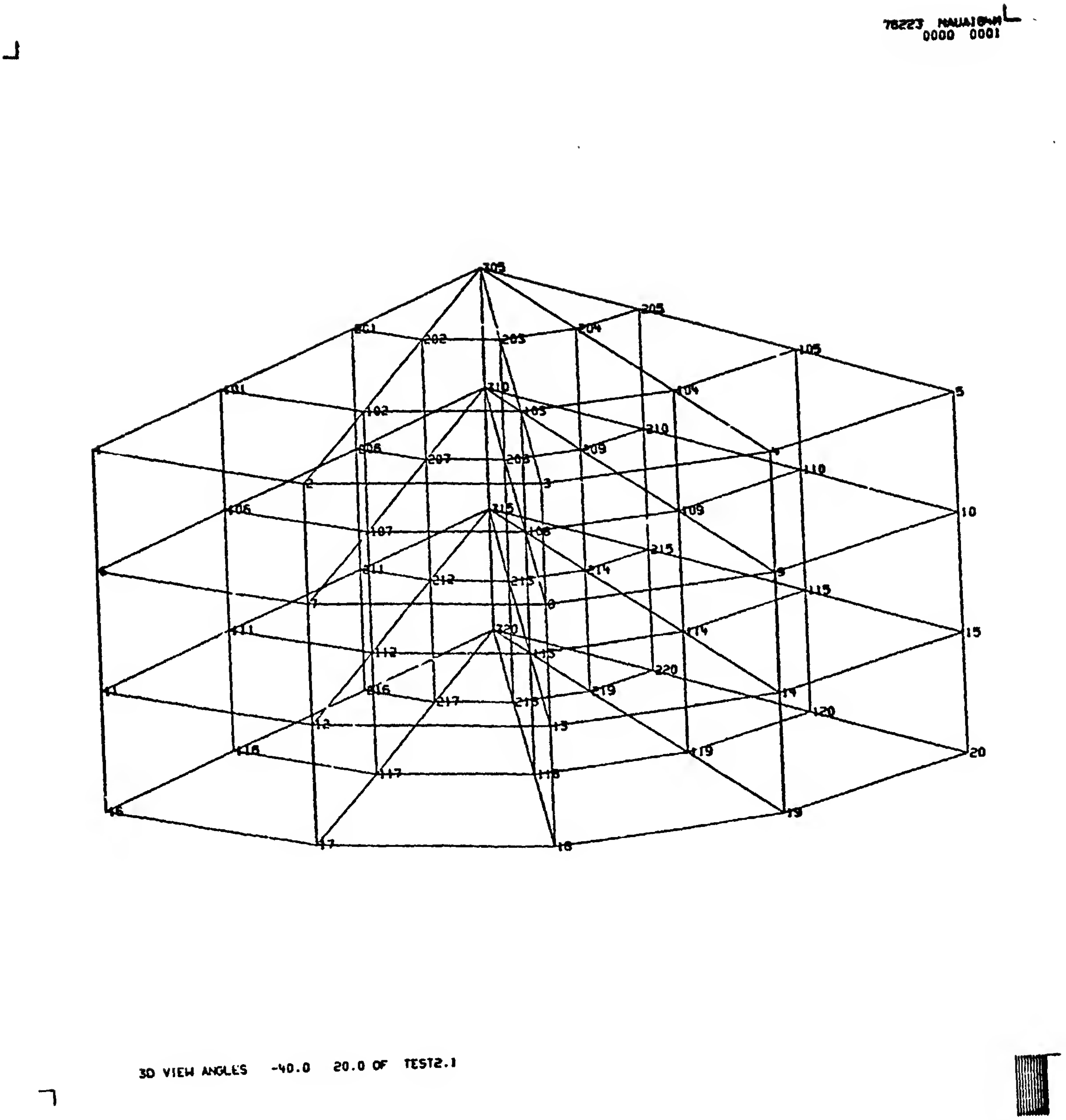


FIGURE 2.1

SAMPLE PROBLEM 2.2

2.2.1 Description:

Model the solid of revolution generated by the sphere $z^2 - 6z + r^2 = 0$ on the interval [3.,6.] as in 1.2. Use HEX1 elements and specify an output coordinate system for displacements CID = 200

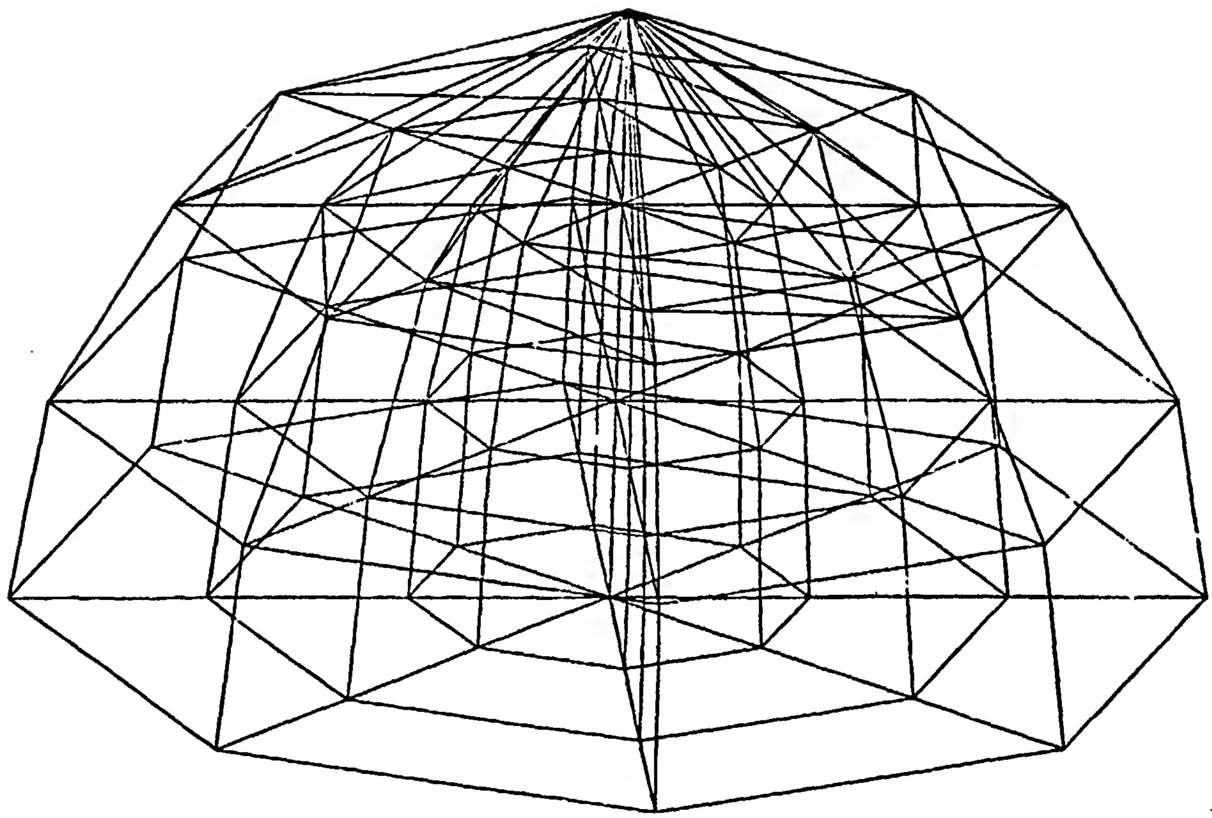
2.2.2 MESHLAN Program:

```
MØDEL TEST2.2
GEØMETRY
    SHAPE = SØLID ØF REVØLUTIØN
    BØUNDARY = FUNCTIØN 2
MESH(,1)
ØPRØP = 200
DIVIDE Z BY 3
    ØUTSYS=200
    NUMBER GRIDS BY 100,ELEMENTS BY 100
        ELEMENTS = FHEX1,1
DIVIDE THETA BY 8
    NUMBER GRIDS BY 1,ELEMENTS BY 1
DIVIDE R BY 3
    NUMBER GRIDS BY 10,ELEMENTS BY 10
PLØT 5.,20.,NØNUM
ENDM
$DATA
FUNCTIØN 2,3.,6.,0.,1.,-6.,1.,0.,0.,0.
```

2.2.3 Model:

The three-dimensional plot for the model is shown in Figure 2.2.

76223 NAUA16NM
0000 0002



3D VIEW ANGLES 5.0 20.0 OF TEST2.2

FIGURE 2.2

SAMPLE PROBLEM 2.3

2.3.1 <u>Description</u>:

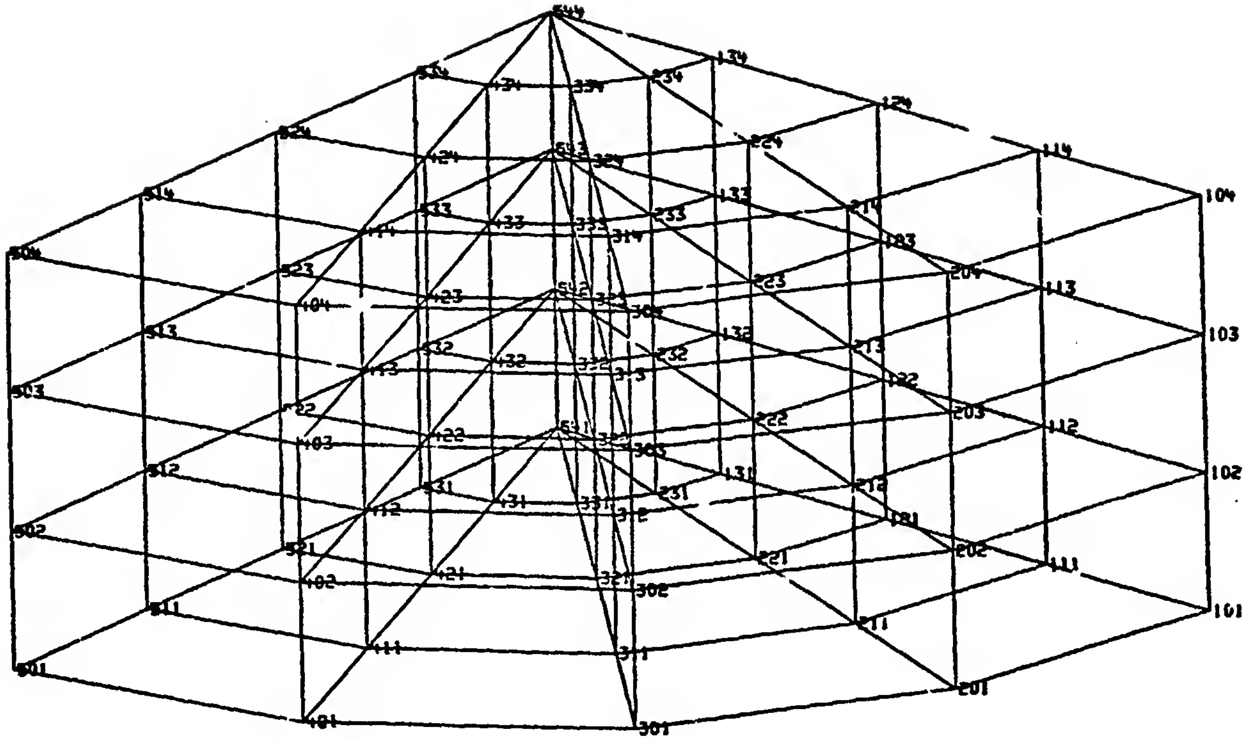
Generate a solid model for the function defined in 1.3.

2.3.2 <u>MESHGEN Program</u>:

```
MØDEL TEST2.3
GEØMETRY
    SHAPE = FLUID
    BØUNDARY = TABLE 48 INTERPØLATE
MESH(,101)
ØPRØP = 200
DIVIDE Z BY 3
    NUMBER GRIDS BY 1,ELEMENTS BY 8
        ELEMENTS = FHEX2,1
STEP THETA FRØM 90.0 TØ 0.0 BY 4
    NUMBER GPIDS BY 100,ELEMENTS BY 1
DIVIDE R BY 4
    NUMBER GRIDS BY 10,ELEMENTS BY 10
PLØT -40.,20.
ENDM
$DATA
TABLE 48,0.,2.,0.,2,4.,0.,4.,2.
```

2.3.3 <u>Model</u>:

Figure 2.3 shows the model generated.



3D VIEW ANGLES -40.0 20.0 OF TEST2.3

FIGURE 2.3

SAMPLE PROBLEM 2.4

2.4.1 Description:

Generate the solid model corresponding to Problem 1.4.

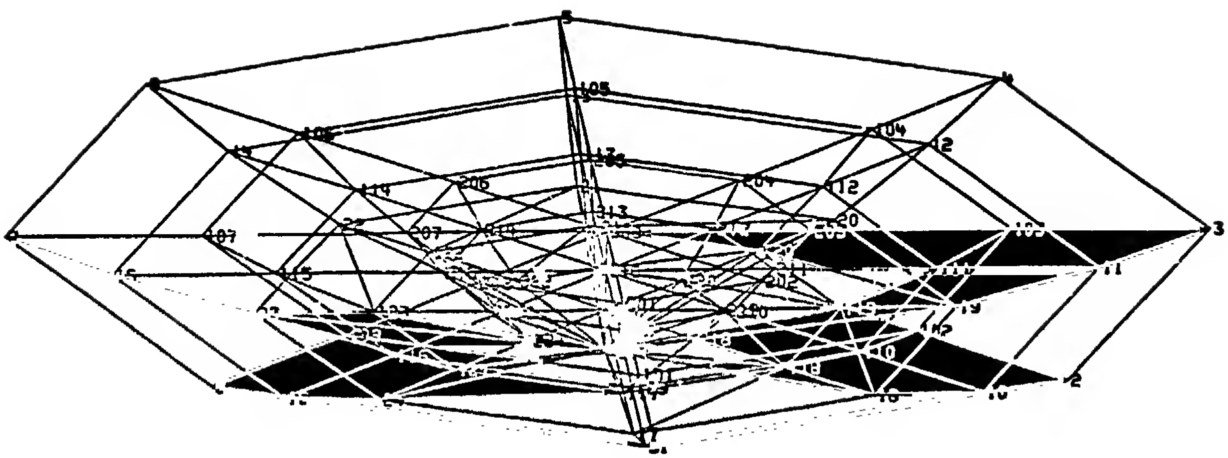
2.4.2 MESHLAN Program:

```
MØDEL TEST2.4
GEØMETRY
    SHAPE = FLUID
    BØUNDARY = FUNCTIØN 3 (1.0)
GRAV = 200
MESH(,1)
ØPRØP = 200
DIVIDE Z BY 3
    NUMBER GRIDS BY 8,ELEMENTS BY 1
        ELEMENTS = FHEX2,1
DIVIDE THETA BY 8
    NUMBER GRIDS BY 1,ELEMENTS BY 3
DIVIDE R BY 3
    NUMBER GRIDS BY 100,ELEMENTS BY 100
PLØT 5.,20.
ENDM
```

2.4.3 Model:

The three-dimensional plot of the model is shown in Figure 2.4.

76223 NAUAI84M
0009 0004



3D VIEW ANGLES 5.0 20.0 OF TEST2.4

FIGURE 2.4

SAMPLE PROBLEM 2.5

2.5.1 Description:

Model a solid of revolution corresponding to 1.7 using explicitly defined axial stations.

2.5.2 MESHLAN Program:

```
MØDEL TEST2.5
GEØMETRY
    SHAPE = FLUID
    BØUNDARY = TABLE 88
MESH(,101)
DIVIDE Z
    NUMBER GRIDS BY 1,ELEMENTS BY 1
        ELEMENTS = FHEX2,1
STEP THETA FRØM 0.0 TØ 90.0 BY 4
    NUMBER GRIDS BY 100, ELEMENTS BY 6
DIVIDE R BY 3
    NUMBER GRIDS BY 1000,ELEMENTS BY 100
PLØT -40.,20.
ENDM
$DATA
TABLE 88,6.,12.,0.,7,6.,6.,5.657,8.,4.472,10.,3.317,
      11.,2.,11.657,1.,11.916,0.,12.
```

2.5.3 Model:

Figure 2.5 illustrates the model generated.

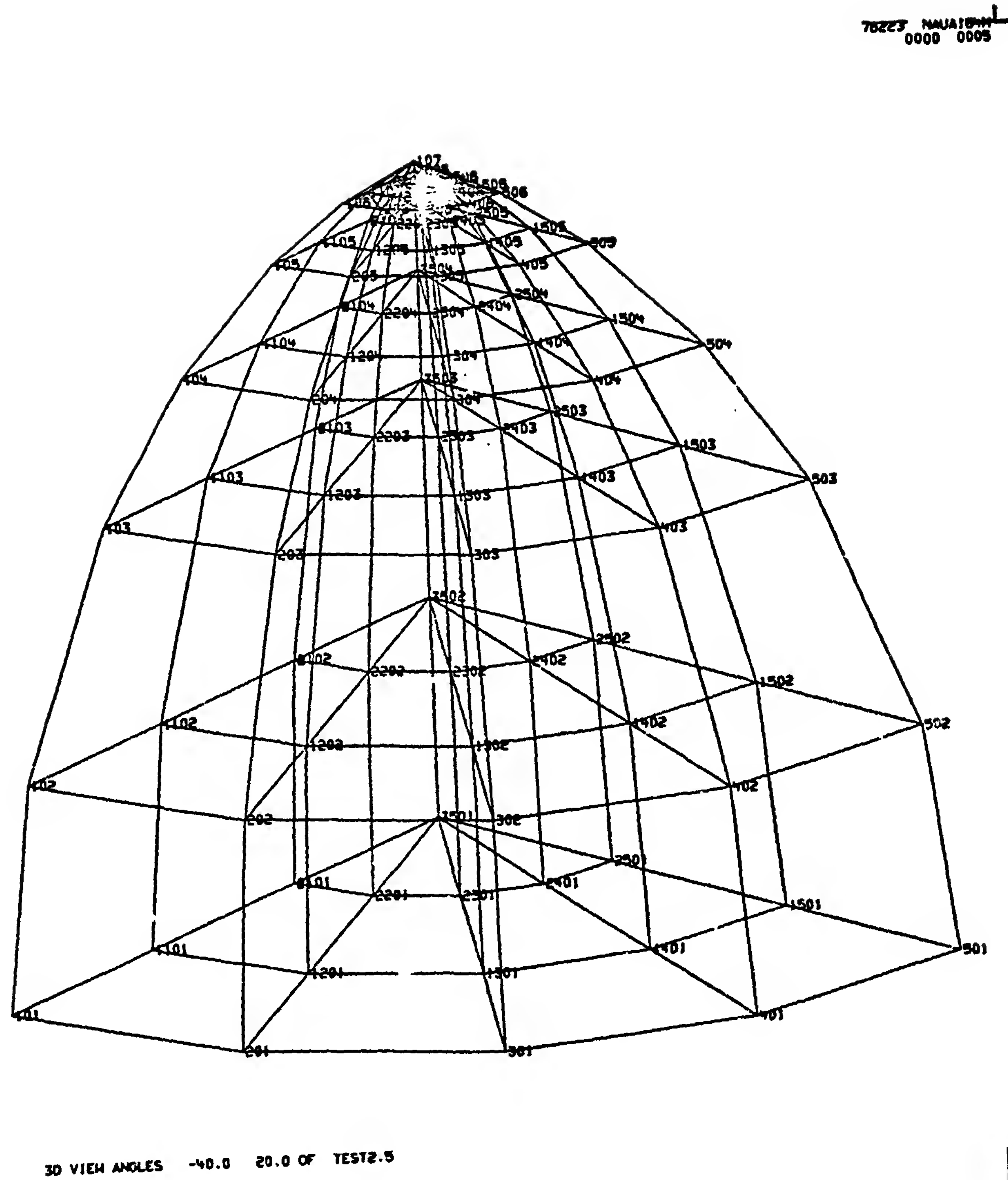


FIGURE 2.5

SAMPLE PROBLEM 3.1

3.1.1 Description:

Generate a three-dimensional model of a 90° segment of a circular cylinder r=5 with a surface tilted 10°.

3.1.2 MESHLAN Program:

```
MØDEL TEST3.1
GEØMETRY
    SHAPE = GFLUID
    BØUNDARY = FUNCTIØN 4 (3.0)
GRAV = 100
MESH(,1)
ØPRØP=200
DIVIDE Z BY 3
    NUMBER GRIDS BY 5,ELEMENTS BY 4
        ELEMENTS = FHEX2,1
STEP THETA FRØM 0.0 TØ 90.0 BY 4
    NUMBER GRIDS BY 1,ELEMENTS BY 1
DIVIDE R BY 3
    NUMBER GRIDS BY 100,ELEMENTS BY 100
PLØT -40.,20.
ENDM
$DATA
FUNCTION 4,3.,0.,10.0,0.,0.,0.,1.,0.,5.
```

3.1.3 Model:

Figure 3.1 illustrates the model generated.

76228 NAUA184M
0000 0001

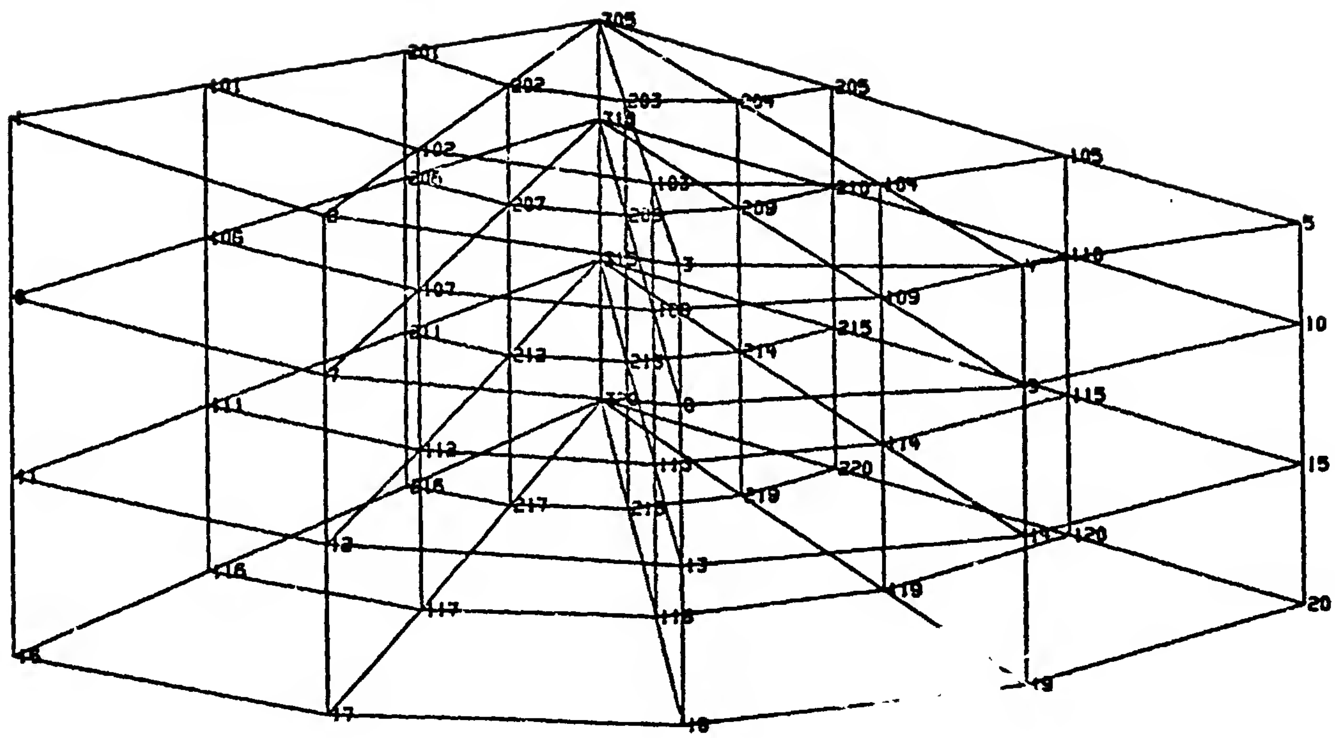


FIGURE 3.1

3D VIEW ANGLES -40.0 20.0 OF TEST3.1

SAMPLE PROBLEM 3.2

3.2.1 Description:

Model a three-dimensional parabolic solid with a tilted surface, $\alpha=5°$.

3.2.2 MESHLAN Program:

```
MØDEL TEST3.2
GEØMETRY
    SHAPE = GFLUID
    BØUNDARY = FUNCTIØN 3 (1.0)
GRAV = 200
MESH(,1)
ØPRØP = 200
DIVIDE Z BY 3
    NUMBER GIRDS BY 8,ELEMENTS BY 1
        ELEMENTS = FHEX2,1
DIVIDE THETA BY 8
    NUMBER GRIDS BY E,ELEMENTS BY 3
DIVIDE R BY 3
    NUMBER GRIDS BY 100,ELEMENTS BY 100
PLØT 5.,20.
ENDM
$DATA
FUNCTION 3,10.0,0.0,5.0,5.,1.,-.04,0.,0.,0.
```

3.2.3 Model:

The three-dimensional MESHGEN plot is shown in Figure 3.2.

c. 2

SAMPLE PROBLEM 4.1

4.1.1 Description:

Model the three-dimensional segment of the cylinder defined in 1.1. Generate both the tank and fluid models in one step.

4.1.2 MESHLAN Program:

```
MØDEL TEST 4.1
GEØMETRY
    SHAPE = TFULL
    BØUNDARY = FUNCTIØN 1(3.0)
GRAV = 200
MESH(1,1001)
DIVIDE Z BY 3
    SHELL
        NUMBER GRIDS BY 5,ELEMENTS BY 4
            ELEMENTS = QUAD2,1
                PRØPERTY = 100
    SØLID
        NUMBER GRIDS BY 5,ELEMENTS BY 4
            ELEMENTS = FHEX2,101
                PRØPERTY = 200
STEP THETA FRØM 0.0 TØ 90.0 BY 4
    SHELL
        NUMBER GRIDS BY 1,ELEMENTS BY 1
    SØLID
        NUMBER GRIDS BY 1,ELEMENTS BY 1
DIVIDE R BY 3
    NUMBER GRIDS BY 100,ELEMENTS BY 100
PLØT -45.,20.
LT2
ENDM
$DATA
FUNCTIØN 1,3.,0.,0.,0.,0.,0.,1.,0.,5.
```

4.1.3 Model:

Two- and three-dimensional plots for the tank are shown in Figures 4.1 and 4.2. The three-dimensional fluid is shown in Figure 4.3.

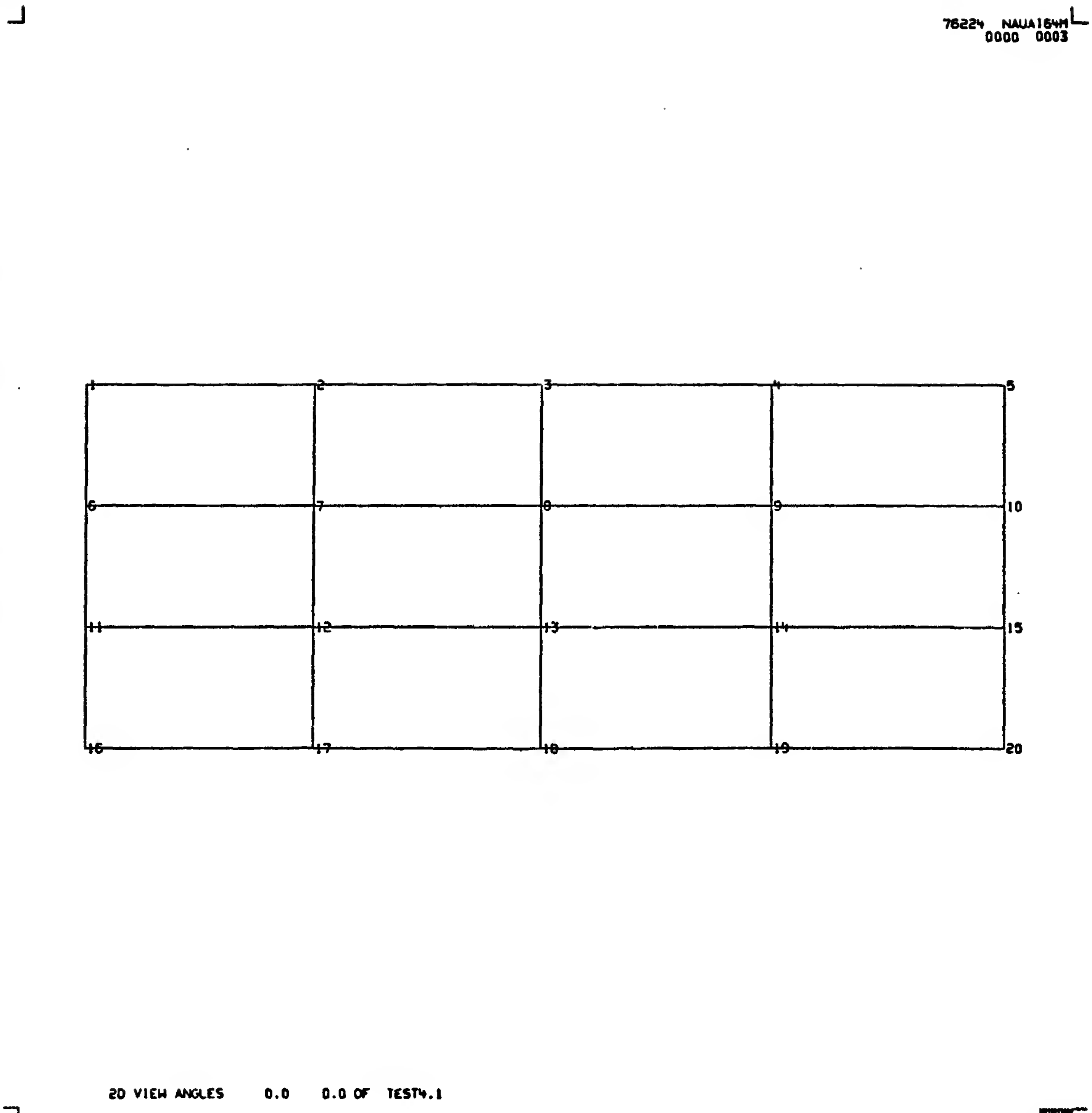
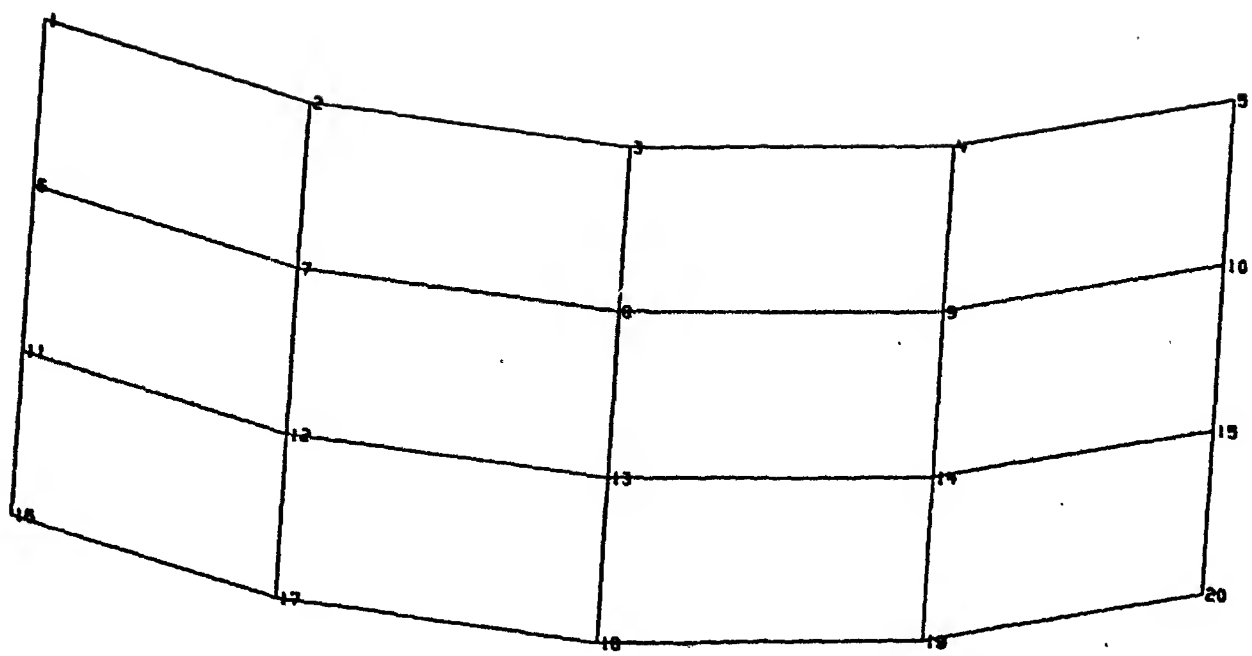

76224 NAUA164M
0000 0003
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
2D VIEW ANGLES 0.0 0.0 OF TEST4.1

FIGURE 4.1

C-2

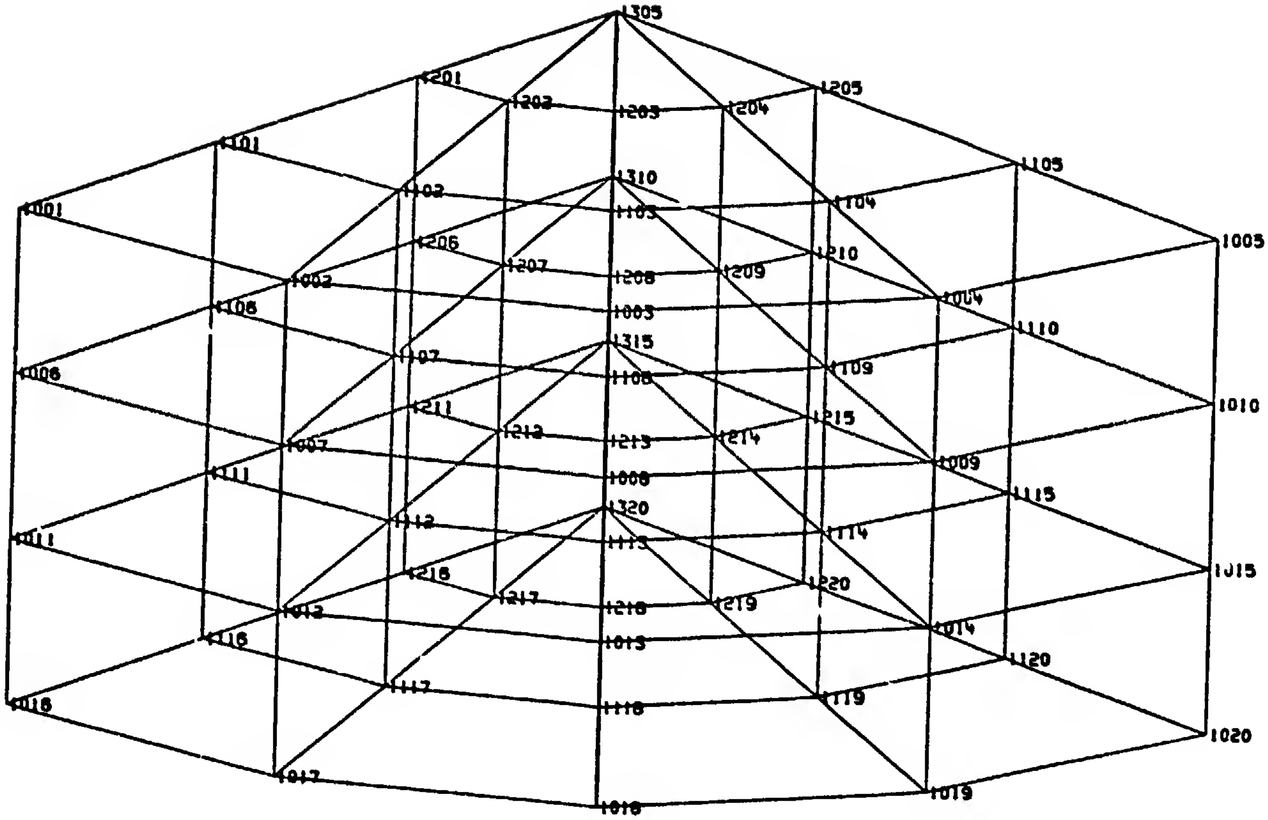
76224 NAVAI84M
0000 0001



3D VIEW ANGLES -45.0 20.0 OF TEST4.1

FIGURE 4.2

78224 NAUA184M
0000 0002



3D VIEW ANGLES -45.0 20.0 OF TEST4.1

FIGURE 4.3

SAMPLE PROBLEM 4.2

4.2.1 Description:

Model a section of a tank/fluid system corresponding to the first five-inch section of the SRI tank.

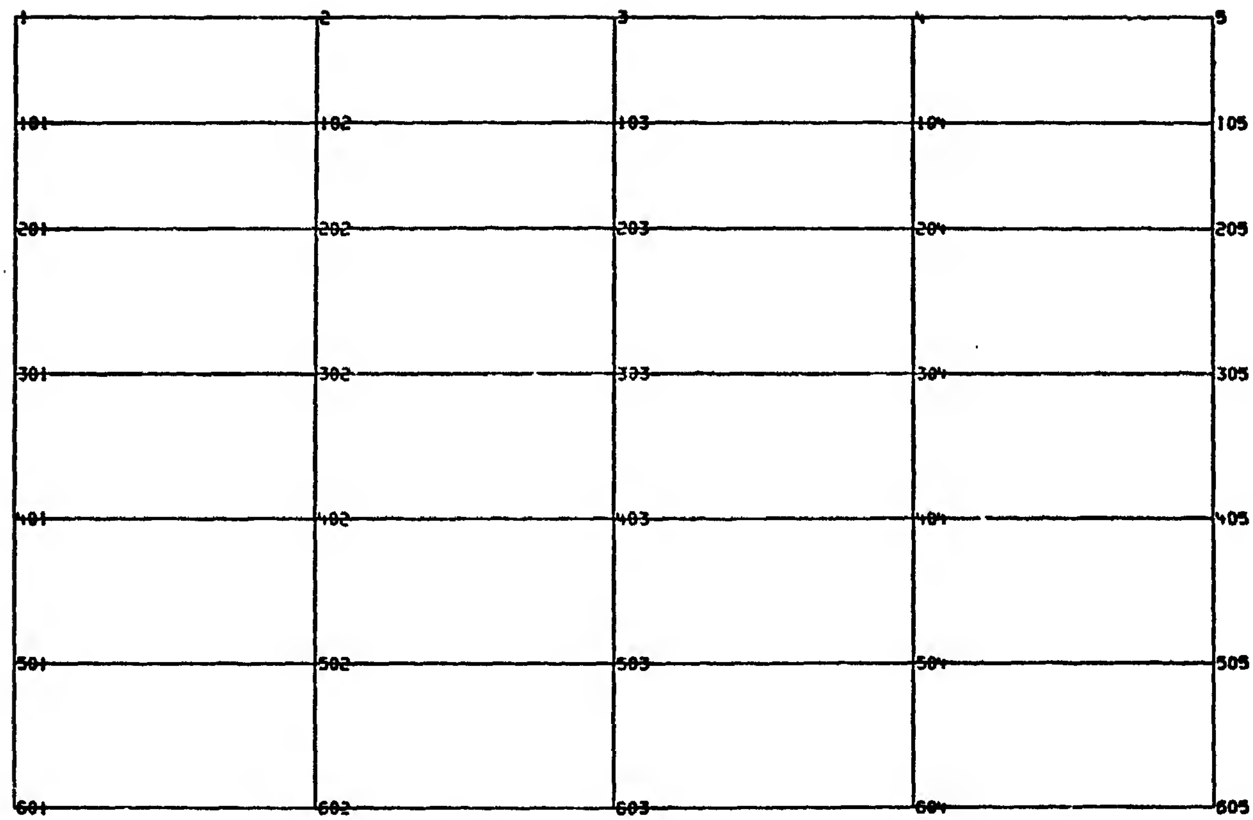
4.2.2 MESHLAN Program:

```
MØDEL TEST4.2
GEØMETRY
    SHAPE = CØNTAINED SØLID
    BØUNDARY = FUNCTIØN 2 (8.66)
GRAV = 200
MESH(1,1001)
ØPRØP = 100
STEP Z FRØM 10.0 TØ 8.66 BY 2
        NUMBER GRIDS BY 100,ELEMENTS BY 100
            ELEMENTS = QUAD2,1
STEP Z FRØM 8.66 TØ 5.0 BY 4
    SHELL
        NUMBER GRIDS BY 100,ELEMENTS BY 100
            ELEMENTS = QUAD2,201
    SØLID
        NUMBER GRIDS BY 100,ELEMENTS BY 100
            ELEMENTS = FHEX2,100
                PRØPERTY = 100
DIVIDE R BY 3
        NUMBER GRIDS BY 10,ELEMENTS BY 10
STEP THETA FRØM 0.0 TØ 90.0 BY 4
    SHELL
        NUMBER GRIDS BY 1,ELEMENTS BY 1
    SØLID
        NUMBER GRIDS BY 1,ELEMENTS BY 1
PLØT -45.,20.
PLT2
ENDM
$DATA
FUNCTIØN 2,10.,5.,0.,0.,0.,0.,1.,0.,5.
```

4.2.3 Model:

Figures 4.4, 4.5 and 4.6 show the two- and three-dimensional shell and three-dimensional fluid, respectively.

76224 NAUA184M
0000 0006


1
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3
4
5
101
102
103
104
105
201
202
203
204
205
301
302
303
304
305
401
402
403
404
405
501
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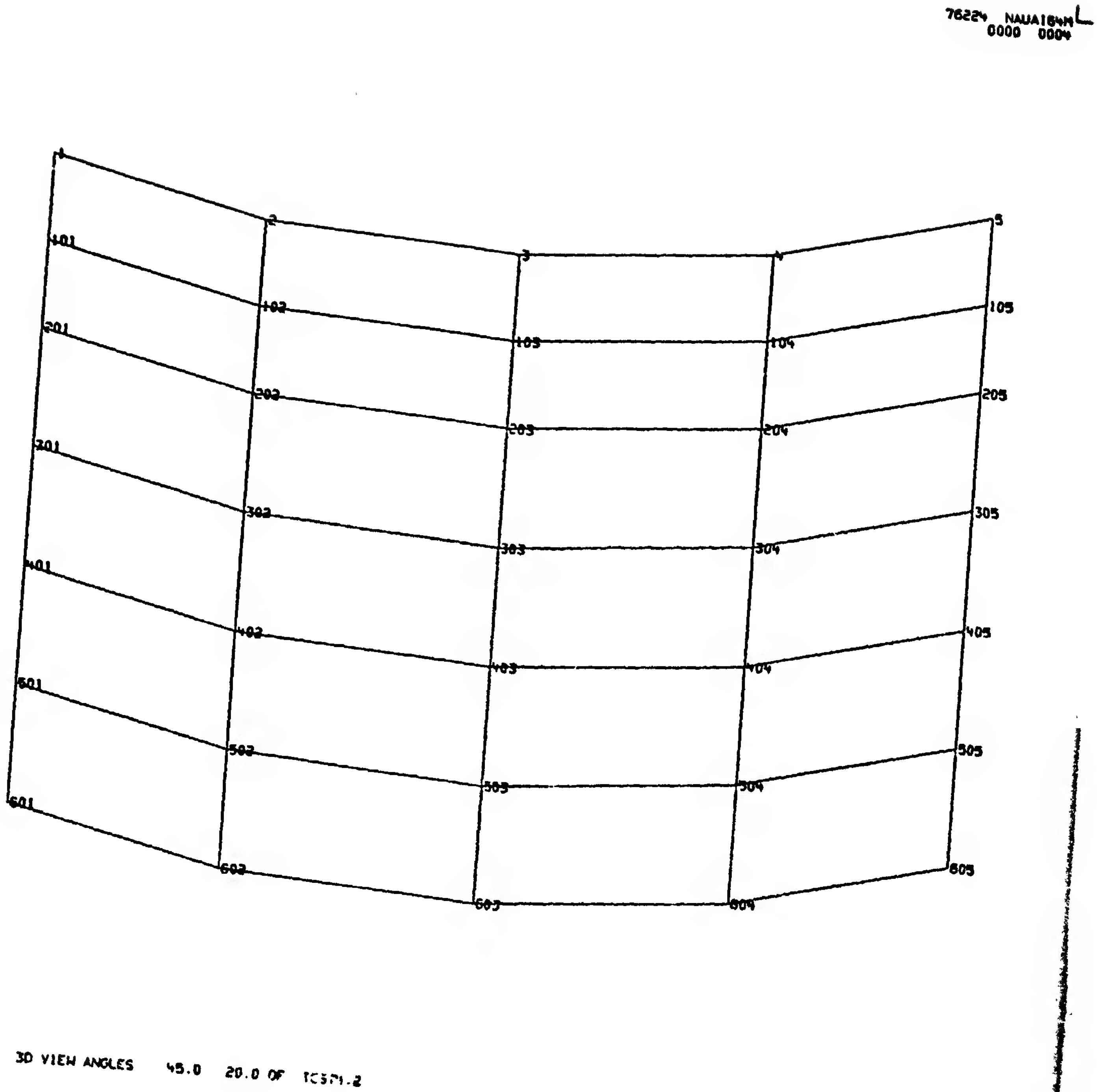
503
504
505
601
602
603
604
605
2D VIEW ANGLES 0.0 0.0 OF TEST4.2

FIGURE 4.4


76224
0000 0004
1
2
3
4
5
101
102
103
104
105
201
202
203
204
205
301
302
303
304
305
401
402
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404
405
501
502
503
504
505
601
602
603
604
605
3D VIEW ANGLES 45.0 20.0 OF

FIGURE 4.5

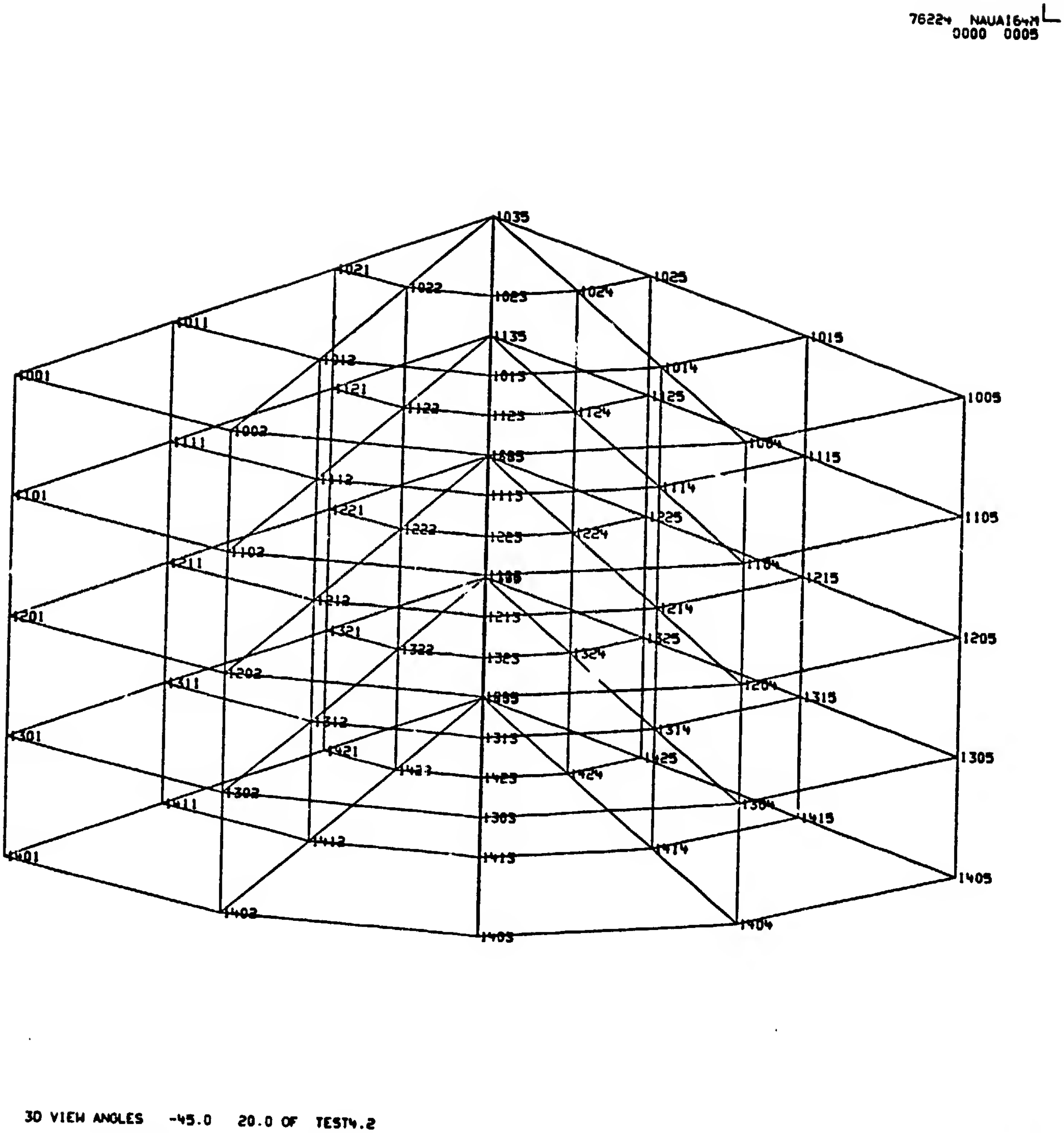

FIGURE 4.6

SAMPLE PROBLEM 5.1

5.1.1 Description:

To Model a 90° sector of a hemisphere defined by a tabular function on the interval z=[1.0,0.0]. The model will be composed of TRIA1 elements and the shell thickness varies uniformly in the axial direction.

5.1.2 MESHLAN Program:

```
MØDEL TEST5.0
GEØMETRY
    SHAPE = CAPS
    BØUNDARY = TABLE 36,INTERPØLATE
MESH(1)
ØPRØP = 100
STEP Z FROM 1.0 TO 0.0 BY 4
    NUMBER GRIDS BY 100,ELEMENTS BY 100
        ELEMENTS = TRIA1,1
            THICKNESS VARIES
STEP THETA FROM 0.0 TO 90.0 BY 4
    NUMBER GRIDS BY 1,ELEMENTS BY 1
PLØT -45.,-20.
PLT2
ENDM
$DATA
TABLE 36,1.0,0.0,0.0,9,0.0,0.0,2.236,.2,2.739,.3,3.162,
      .4,3.536,.5,3.873,.6,4.183,.7,4.472,.8,5.,1.0
```

5.1.3 Model:

Figures 5.1 and 5.2 show the two- and three-dimensional MESHGEN plots.

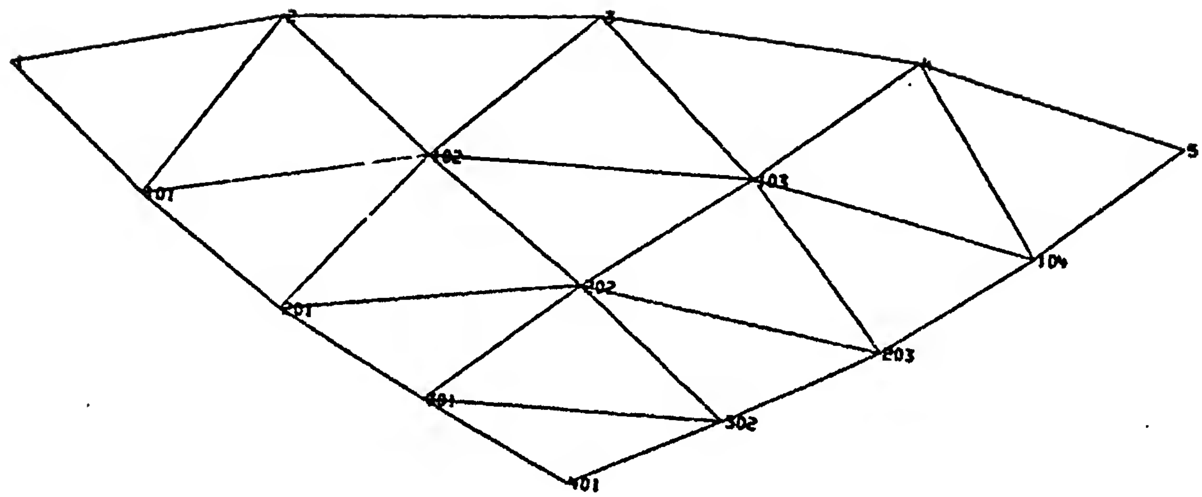

FIGURE 5.1

75220 NAUAI84M
0000 0002

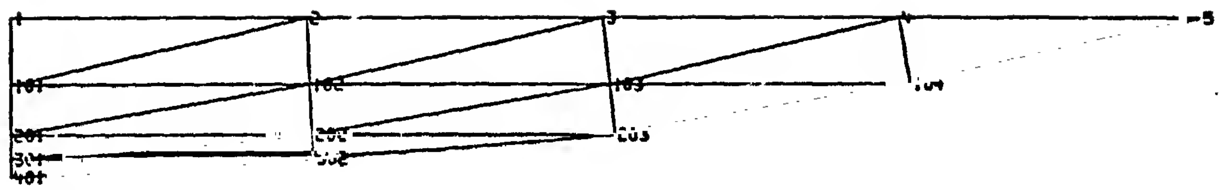

FIGURE 5.2

SAMPLE PROBLEM 5.2

5.2.1 Description:

To model a 120° sector of a hemisphere defined by a tabular function on the interval z=[6.0,12.0]. The model will be composed of TRBSC elements with constant properties.

5.2.2 MESHLAN Program:

```
MØDEL TEST5.2
GEØMETRY
    SHAPE = CAPS
    BØUNDARY = TABLE 88,INTERPØLATE
MESH(1)
ØPRØP = 100
DIVIDE Z BY 4
    NUMBER GRIDS BY 1,ELEMENTS BY 100
        ELEMENTS = TRBSC,1
STEP THETA FROM 0.0 TO 120.0 BY 4
    NUMBER GRIDS BY 100,ELEMENTS BY 1
PLØT -60.,20.
PLT2
$DATA
TABLE 88,6.,12.,0.,7,6.,6.,5.657,8.,4.472,10.,3.317,
      11.,2.,11.657,1.,11.716,0.,12.
```

NOTE: When specifying the boundary of a CAPSHELL the Z1 and Z2 values on the FUNCTION or TABLE data cards must correspond to the open and closed ends of the idealization, respectively.

5.2.3 Model:

Two- and three-dimensional plots are shown in Figures 5.3 and 5.4.

76220 NAVAIRWM 0000 0003

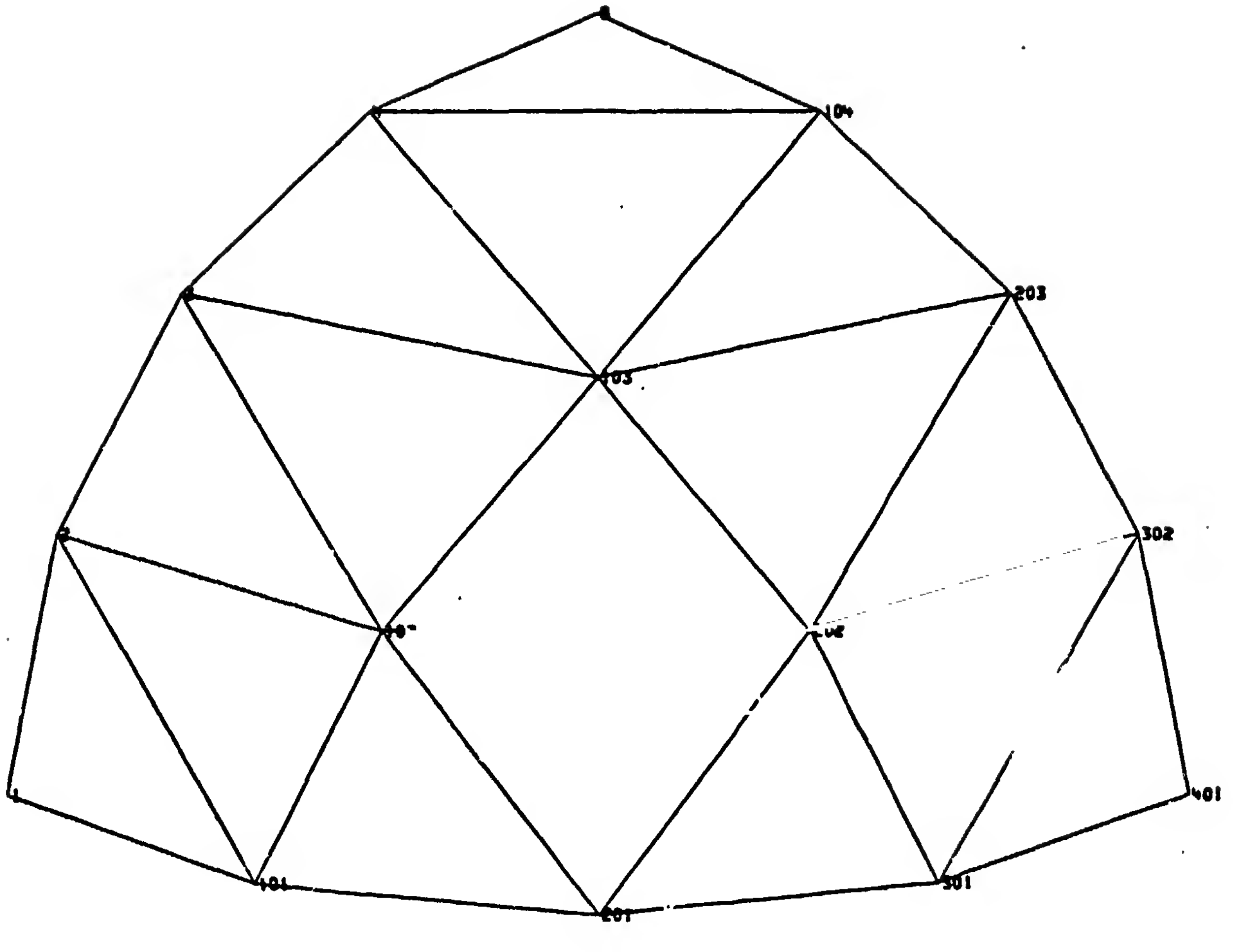

FIGURE 5.3

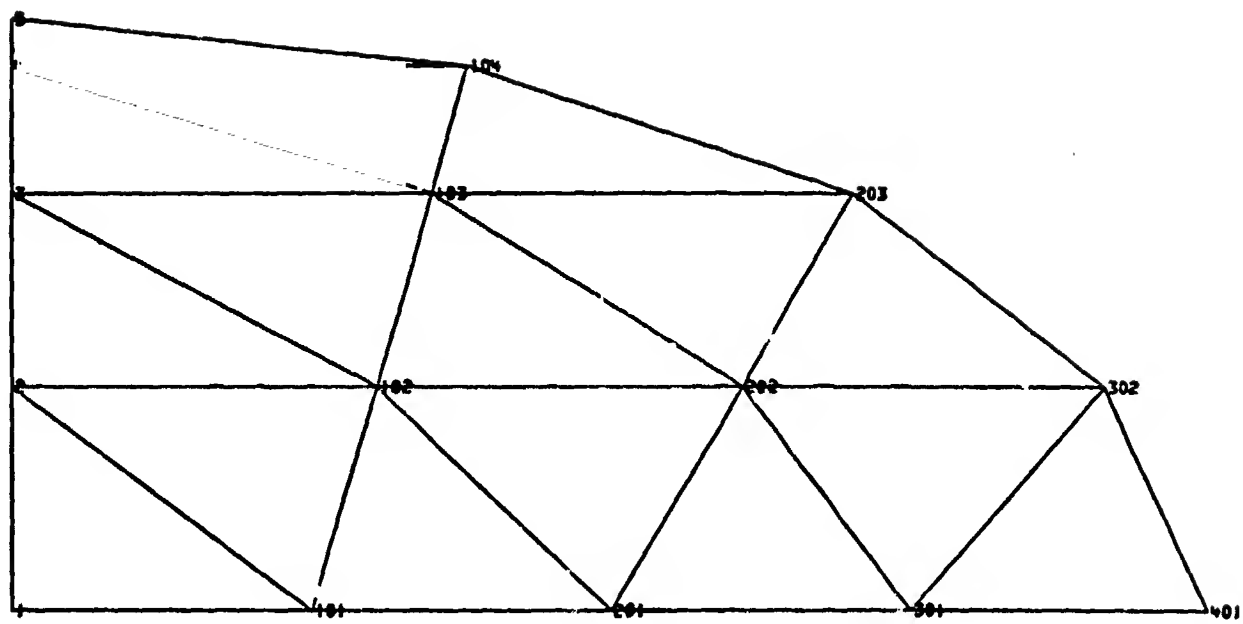

FIGURE 5.4

SAMPLE PROBLEM 5.3

5.3.1 Description:

To model a 90° sector of a shell defined by the parabola $25z=r^2$ on the interval [1.0,0.0]. The model will contain double elements (overlapping) of types TRIA1 and TRMEM each with different, but uniform, properties. The top ring (z=1.0) will be fixed, and symmetric boundaries imposed at θ=0° and θ=90°.

5.3.2 MESHGEN Program:

```
MØDEL TEST5.3
GEØMETRY
    SHAPE = CAPS
    BØUNDARY = FUNCTIØN 2
MESH(101)
DIVIDE Z BY 6
    NUMBER GRIDS BY 10,ELEMENTS BY 20
        ELEMENTS = TRIA1,1
            PRØPERTY = 10
        ELEMENTS = TRMEM,1001
            PRØPERTY = 38
    FIX 123456 AT (1.0)
STEP THETA FROM 90.0 TO 0.0 BY 6
    NUMBER GRIDS BY 1,ELEMENTS BY 1
    FIX 246 AT (0.0,90.0)
PLØT -45.,-20.
ENDM
FUNCTIØN 2,1.0,0.0,0.,0.,1.,-4.,0.,0.,0.
```

5.3.3 Model:

A three-dimensional structure plot is shown in Figure 5.5.

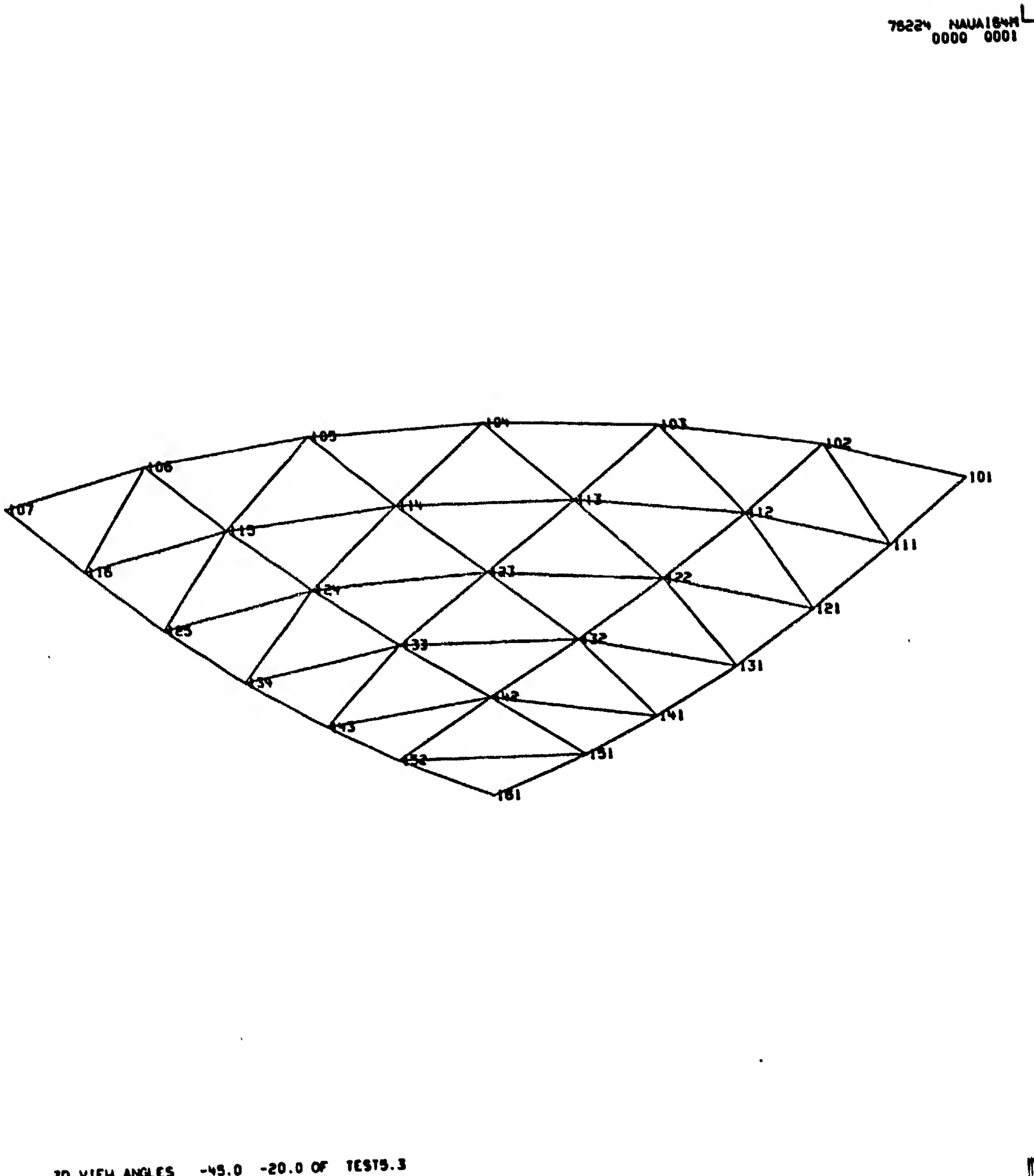
78224 NAUA184M
0000 0001
107
106
105
104
103
102
101
116
115
114
113
112
111
125
124
123
122
121
134
133
132
131
143
142
141
152
151
161
3D VIEW ANGLES -45.0 -20.0 OF TEST5.3

FIGURE 5.5

SAMPLE PROBLEM 5.4

5.4.1 Description:

To model a tank closure using the CAPSHELL for the tank defined in sample problem 1.8C.

5.4.2 MESHLAN Program:

```
MØDEL TEST5.4
GEØMETRY
    SHAPE = CAPS
    BØUNDARY = TABLE 73 INTERPØLATE
MESH(901)
DIVIDE Z BY 4
    NUMBER GRIDS BY 100,ELEMENTS BY 10
        ELEMENTS = TRIA2,81
STEP THETA FROM 0.0 TO 90.0 BY 3
    FIX 246 AT (0.0,90.0)
    NUMBER GRIDS BY 10,ELEMENTS BY 1
PLØT -45.,-20.
ENDM
$DATA
TABLE 73,3.,0.,0.,7,0.,0.,1.,.3,2.,.7,3.,1.1,4.,1.6,
      5.,2.25,6.,3.
```

5.4.3 Model:

Figure 5.6 shows a three-dimensional MESHGEN plot of this model.

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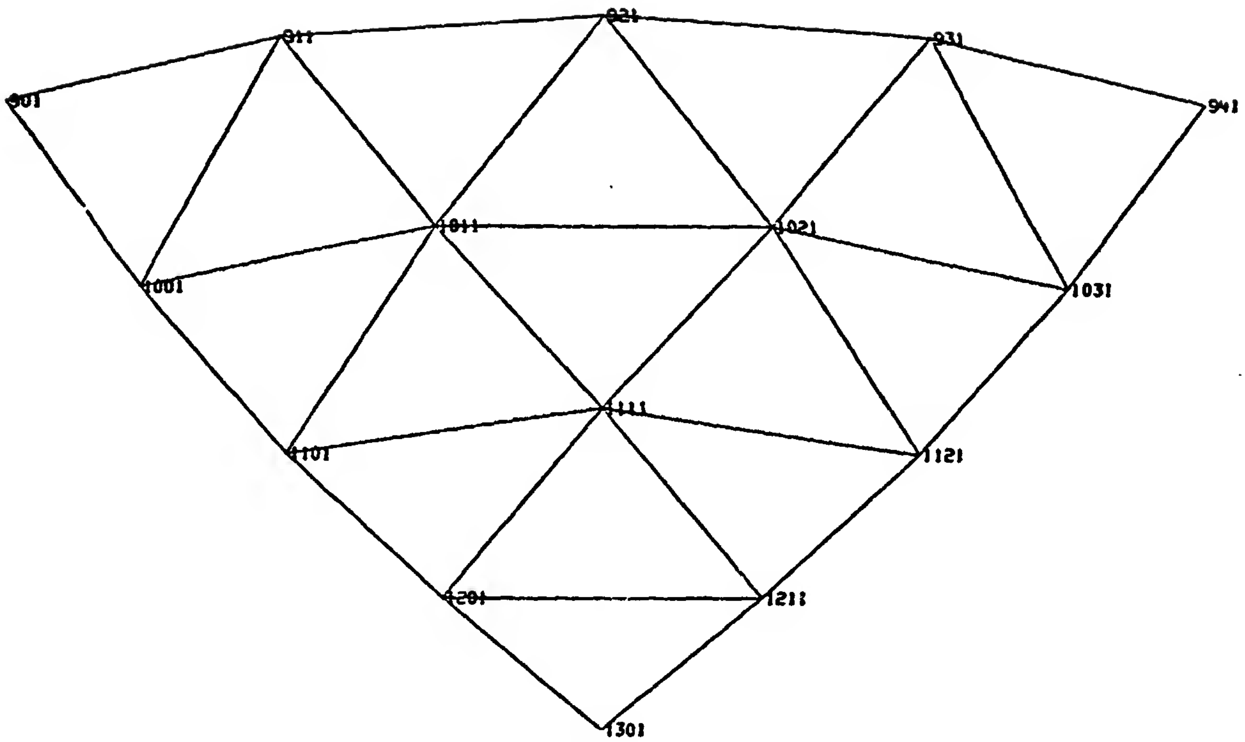

3D VIEW ANGLES -45.0 -20.0 OF TEST5.4

FIGURE 5.6

SAMPLE PROBLEM 6.1

6.1.1 Description:

Model a quadrant of the hemisphere defined by $z^2 + r^2 = 25$ on the interval [.,-5.]. Use FWEDGE elements.

6.1.2 MESHLAN Program:

```
MØDEL TEST6.1
GEØMETRY
    SHAPE = CAPFLUID
    BØUNDARY = FUNCTIØN 8
MESH(,1)
DIVIDE Z BY 4
    NUMBER GRIDS BY 100,ELEMENTS BY 100
        ELEMENTS = FWEDGE,1
STEP THETA FRØM 0.0 TØ 90.0 BY 2
    NUMBER GRIDS BY 1,ELEMENTS BY 1
DIVIDE R
    NUMBER GRIDS BY 10,ELEMENTS BY 10
PLØT -40.,20.,NØNUM
ENDM
$DATA
FUNCTIØN 8,0.,-5.,0.,1.,0.,1.,0.,5.,0.
```

NOTE: The command DIVIDE R does not need an increment since the number of R steps must equal the z division. The value of z1 in the FUNCTION (or TABLE) definition must be the open end of the solid. CAPFLUID SHAPES may not produce plots via the PLT2 option.

6.1.3 Model:

Figure 6.1 illustrates the three-dimensional model.

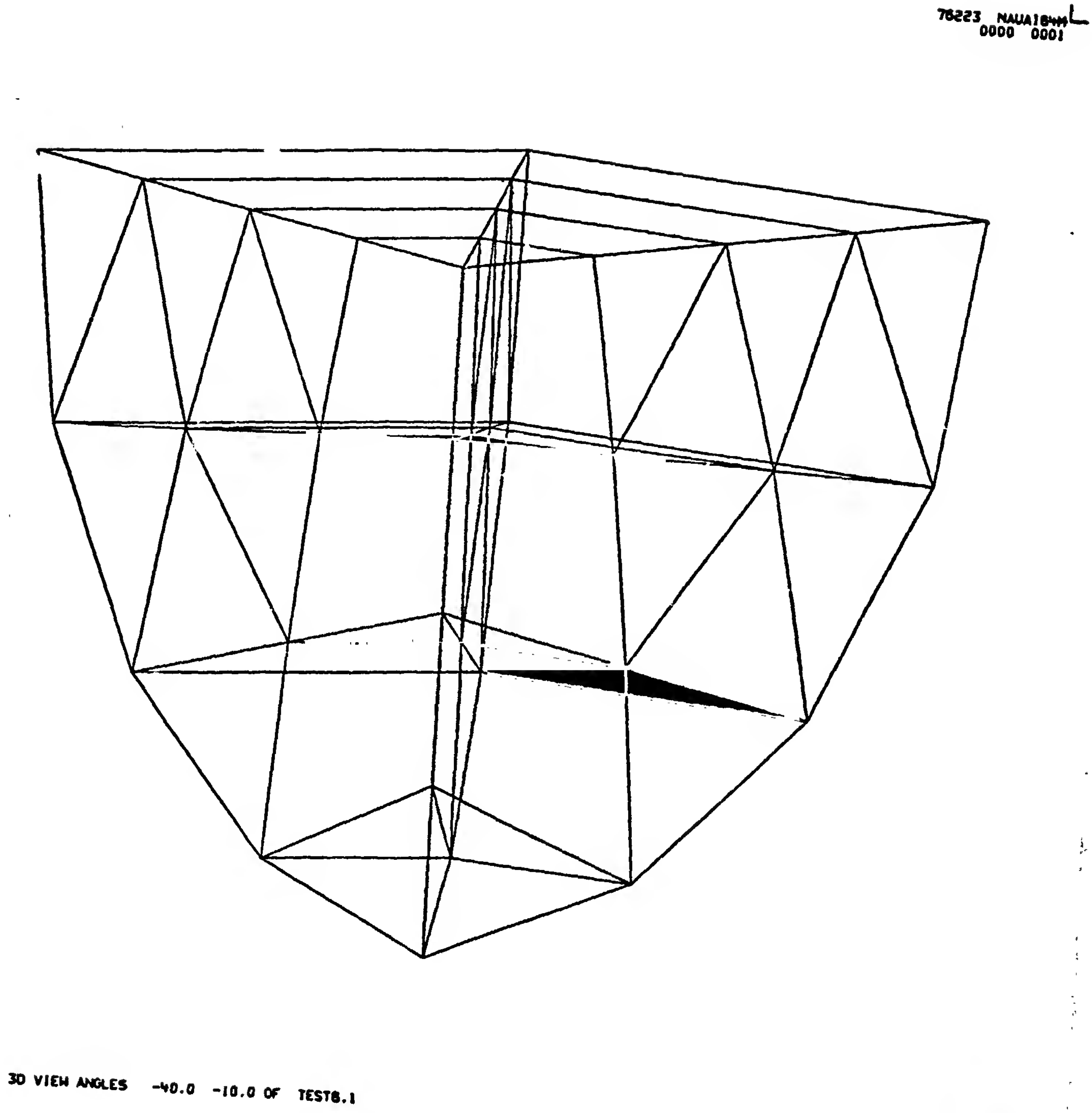

FIGURE 6.1

SAMPLE PROBLEM 6.2

6.2.1 Description:

Model half of the body generated by the parabola $25z = r^2$ on the interval z=[4.0,0.]. Use FHEX2 elements.

6.2.2 MESHLAN Program:

```
MØDEL TEST6.2
GEØMETRY
    SHAPE = CAPF
    BØUNDARY = FUNCTIØN 1
MESH(,1)
DIVIDE Z BY 4
    NUMBER GRIDS BY 50,ELEMENTS BY 50
        ELEMENTS = FHEX2,1
STEP THETA FRØM 90.0 TØ 0.0 BY 2
    NUMBER GRIDS BY 1,ELEMENTS BY 1
DIVIDE R
    NUMBER GRIDS BY 10,ELEMENTS BY 10
PLØT -40.0,-20.0
ENDM
$DATA
FUNCTIØN 1,4.0,0.0,0.,0.,25.,-1.,0.,0.,0.
```

6.2.3 Model:

Figure 6.2 shows the three-dimensional model.

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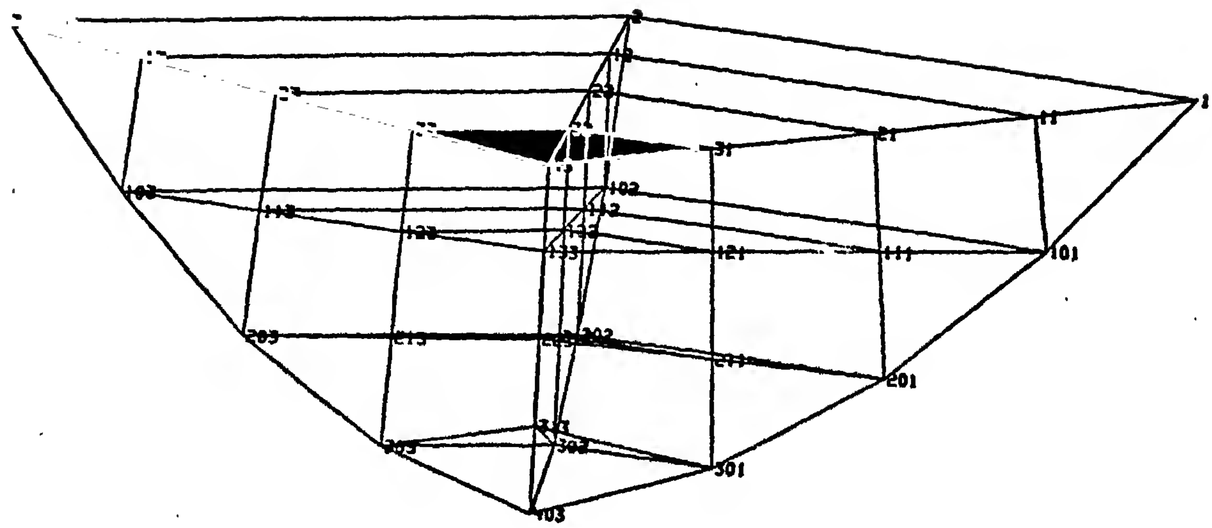
0000 0003



3D VIEW ANGLES -40.0 -10.0 OF TEST6.2

FIGURE 6.2

SAMPLE PROBLEM 6.3

6.3.1 Description:

Generate a model for a hemisphere defined by $z^r + r^2 = 25$ cn the interval [0.0,5.0]. Use FWEDGE elements.

6.3.2 MESHLAN Program:

```
MØDEL TEST6.3
GEØMETRY
    SHAPE = CAPF
    BØUNDARY = FUNCTIØN 3
MESH(,1)
DIVIDE Z BY 5
    NUMBER GRIDS BY 100,ELEMENTS BY 100
        ELEMENTS = FWEDGE,1
DIVIDE THETA BY 8
    NUMBER GRIDS BY 1,ELEMENTS BY 1
DIVIDE R
    NUMBER GRIDS BY 10,ELEMENTS BY 10
PLØT -5.,-20.,NØNUM
PLT2
ENDM
$DATA
FUNCTIØN 3,0.,5.,0.,1.,0.,1.,0.,5.,0.
```

6.3.3 Model:

A three-dimensional MESHGEN plot is shown in Figure 6.3.

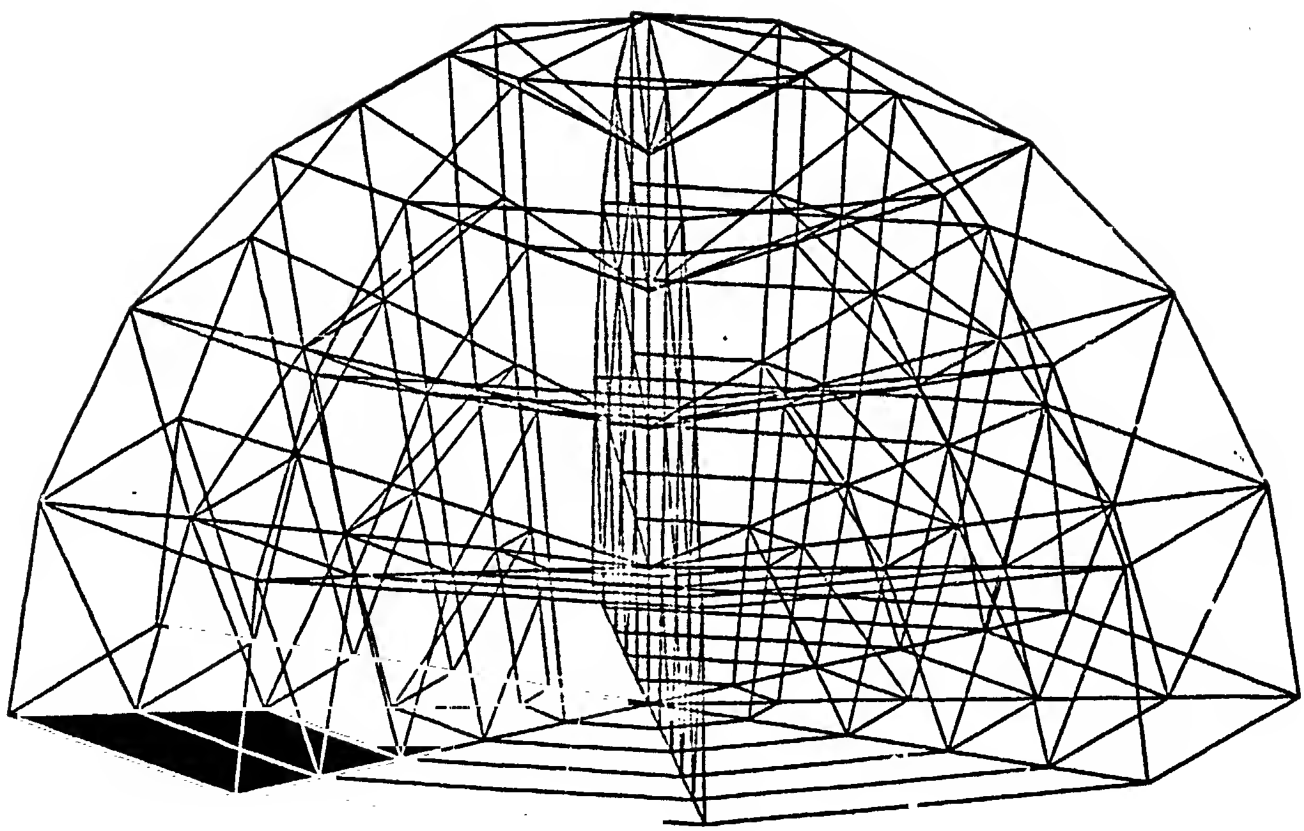


FIGURE 6.3

3D VIEW ANGLES -5.0 -10.0 OF TEST6.3

SAMPLE PROBLEM 7.1

7.1.1 Description:

Generate a model for the upper hemisphere of the sphere $z^2 + r^2 = 25$ on z=[0.,5.]. Include both fluid and structure models.

7.1.2 MESHLAN Program:

```
MØDEL TEST7.1
GEØMETRY
    SHAPE = CAPB
    BØUNDARY = FUNCTIØN 1
GRAVITY = 1
MESH(1,1001)
DIVIDE Z BY 4
    SHELL
        NUMBER GRIDS BY 100,ELEMENTS BY 100
            ELEMENTS = TRMEM,1
                PRØPERTY = 100
    SØLID
        NUMBER GRIDS BY 100,ELEMENTS BY 100
            ELEMENTS = FWEDGE,1001
                PRØPERTY = 200
STEP TEHTA FROM 0.0 TO 90.0 BY 4
    SHELL
        NUMBER GRIDS BY 1,ELEMENTS BY 1
    SØLID
        NUMBER GRIDS BY 1,ELEMENTS BY 1
DIVIDE R
        NUMBER GRIDS BY 10,ELEMENTS BY 10
PLØT -45.,20.
PLT2
ENDM
$DATA
FUNCTION 1,0.,5.,0.,1.,0.,1.,0.,5.,0.
```

7.1.3 Model:

The two- and three-dimensional MESHGEN plots of this model are shown in Figures 7.1 - 7.3.

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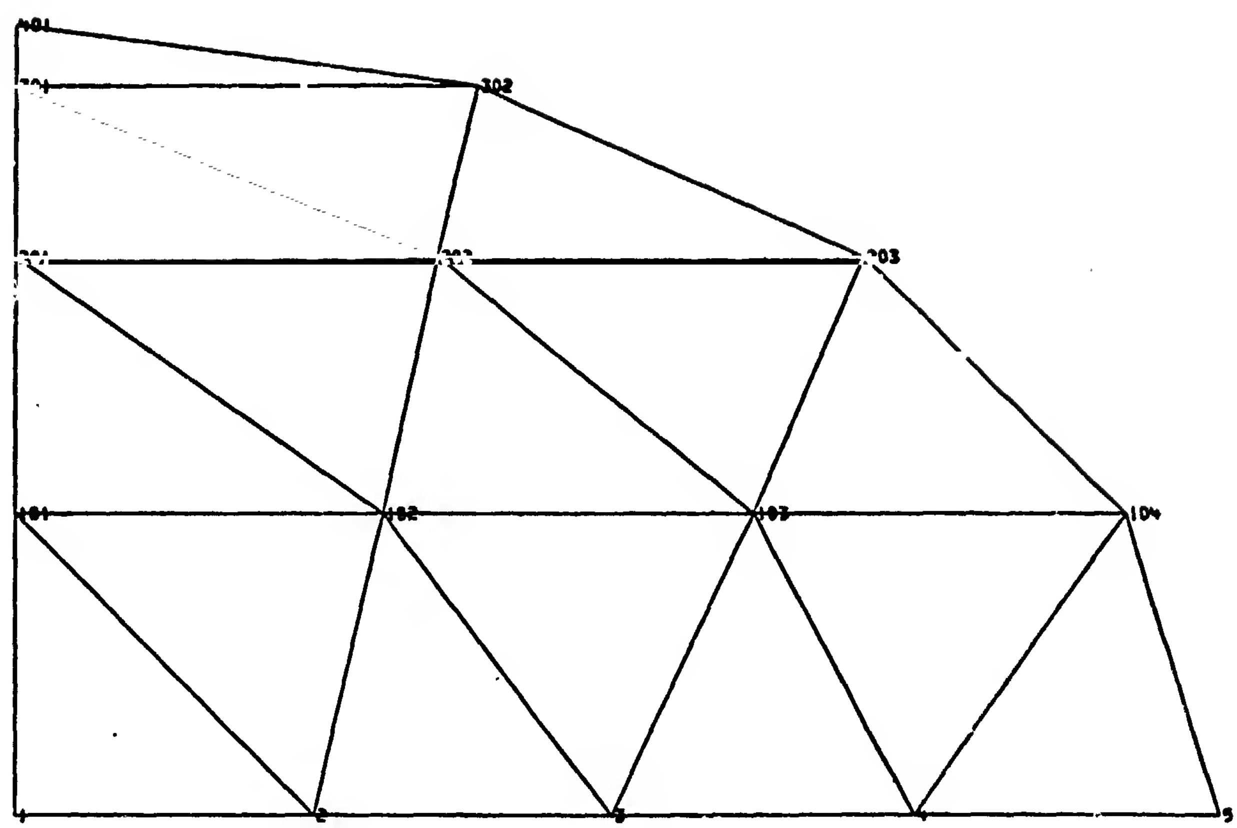
0000 0001



2D VIEW ANGLES 0.0 0.0 OF TEST7.1

FIGURE 7.1

76224 NAUA184M
0000 0002

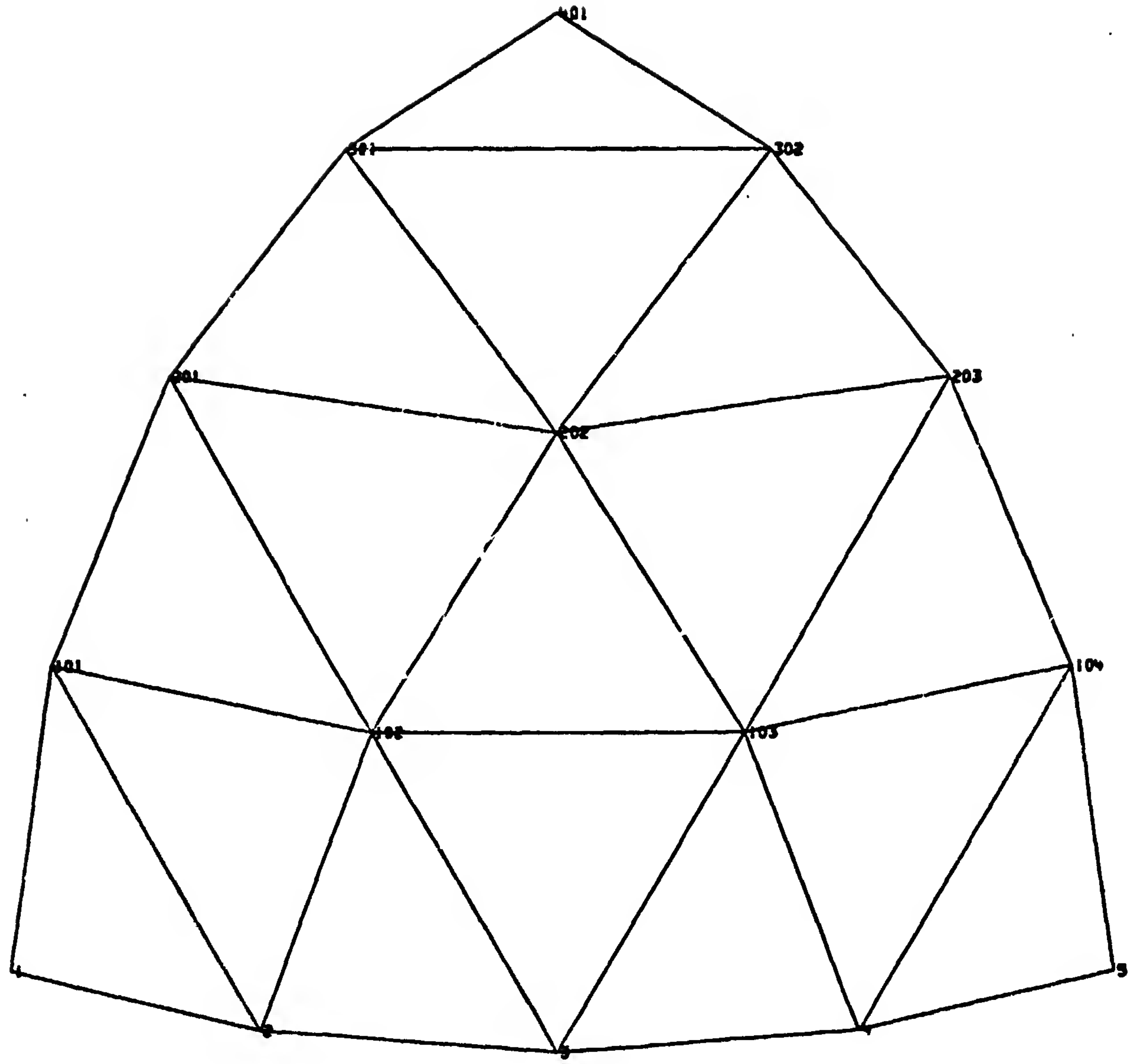


FIGURE 7.2

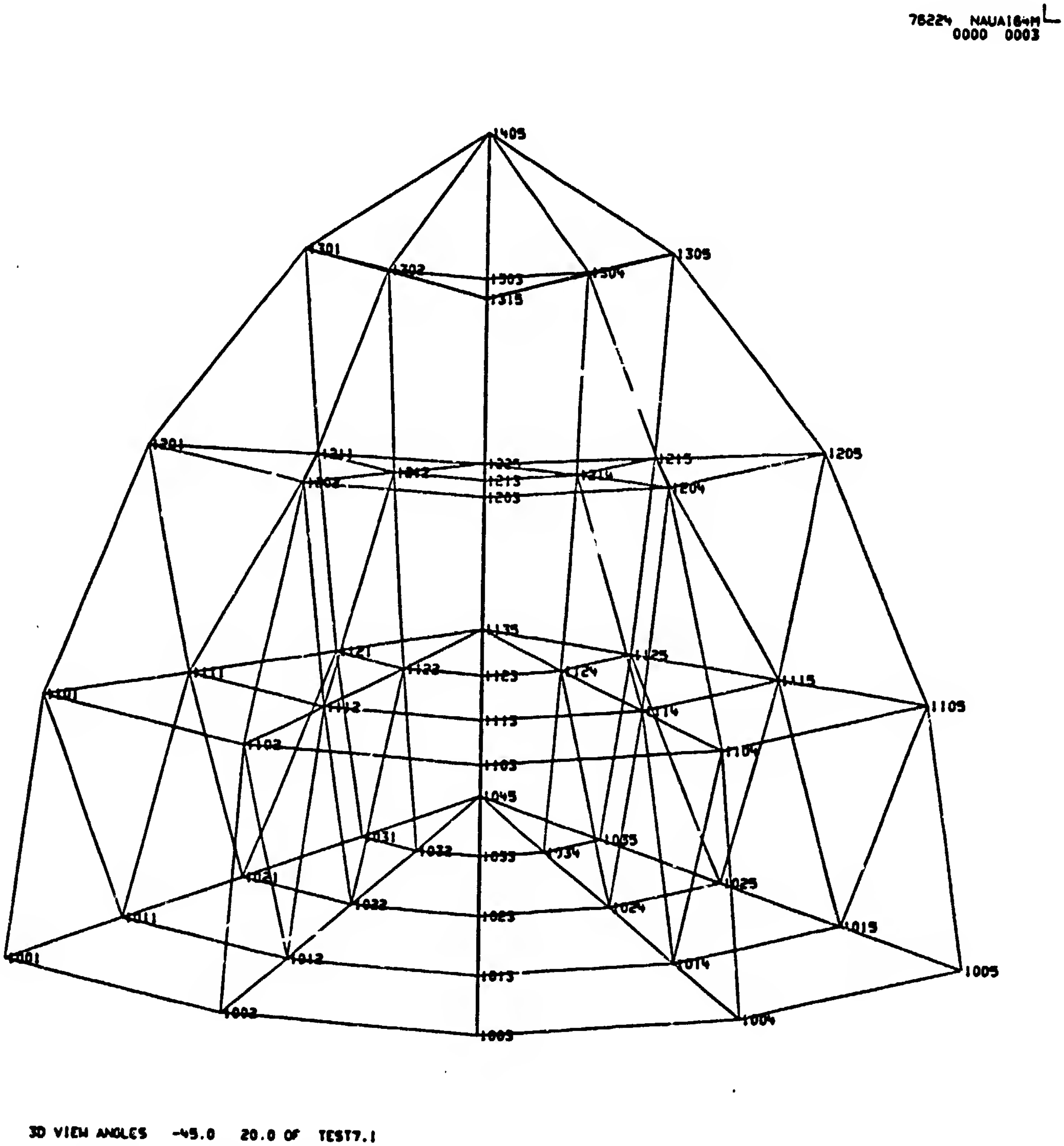

76224 NAUA184M
0000 0003
1405
1301
1302
1303
1315
1304
1305
1201
1205
1204
1203
1105
1101
1103
1104
1135
1045
1005
1001
1003
1004
1013
1023
1033
3D VIEW ANGLES -45.0 20.0 OF TEST7.1

FIGURE 7.3

SAMPLE PROBLEM 7.2

7.2.1 Description:

Generate a model for the same function as problem 7.1 on the interval [0,-5.].

7.2.2 MESHLAN Program:

```
MØDEL TEST7.2
GEØMETRY
    SHAPE = CAPB
    BØUNDARY = FUNCTIØN 2
GRAVITY = 225
MESH(1,1001)
DIVIDE Z BY 4
    SHELL
        NUMBER GRIDS BY 100,ELEMENTS BY 100
            ELEMENTS = TRIA1,1
                PRØPERTY = 100
    SØLID
        NUMBER GRIDS BY 100,ELEMENTS BY 100
            ELEMENTS = FWEDGE,1001
                PRØPERTY = 200
STEP THETA FROM 0.0 TO 90.0 BY 4
    SHELL
        NUMBER GRIDS BY 1,ELEMENTS BY 1
    SØLID
        NUMBER GRIDS BY 1,ELEMENTS BY 1
DIVIDE $
        NUMBER GRIDS BY 10,ELEMENTS BY 10
PLØT -45.,20.
PLT2
ENDM
$DATA
FUNCTIØN 2,0.,-5.,0.,1.,0.,1.,0.,5.,0.
```

NOTE: For a CAPB SHAPE option, the value z, on the FUNCTION card (or TABLE) must define the open end of the figure

7.2.3 Model:

Figures 7.4 - 7.5 show the two- and three-dimensional MESHGEN plots.

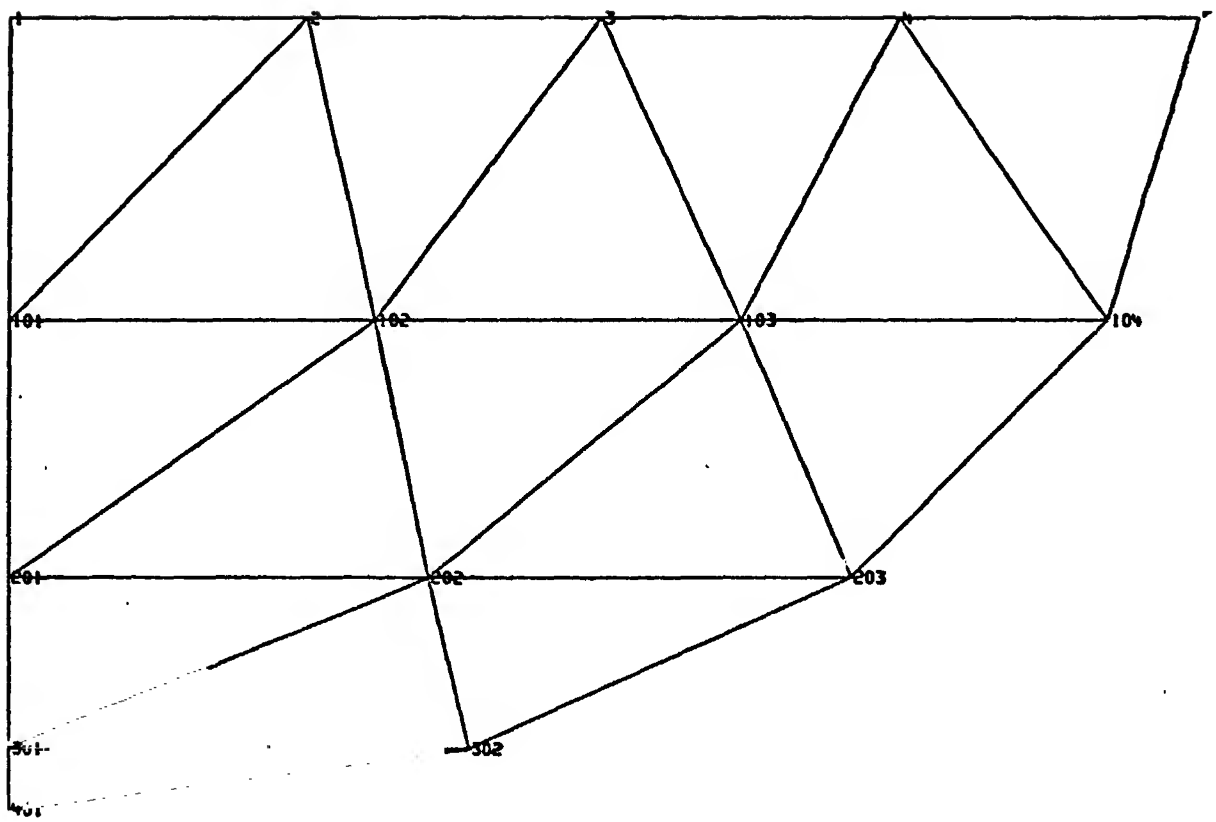
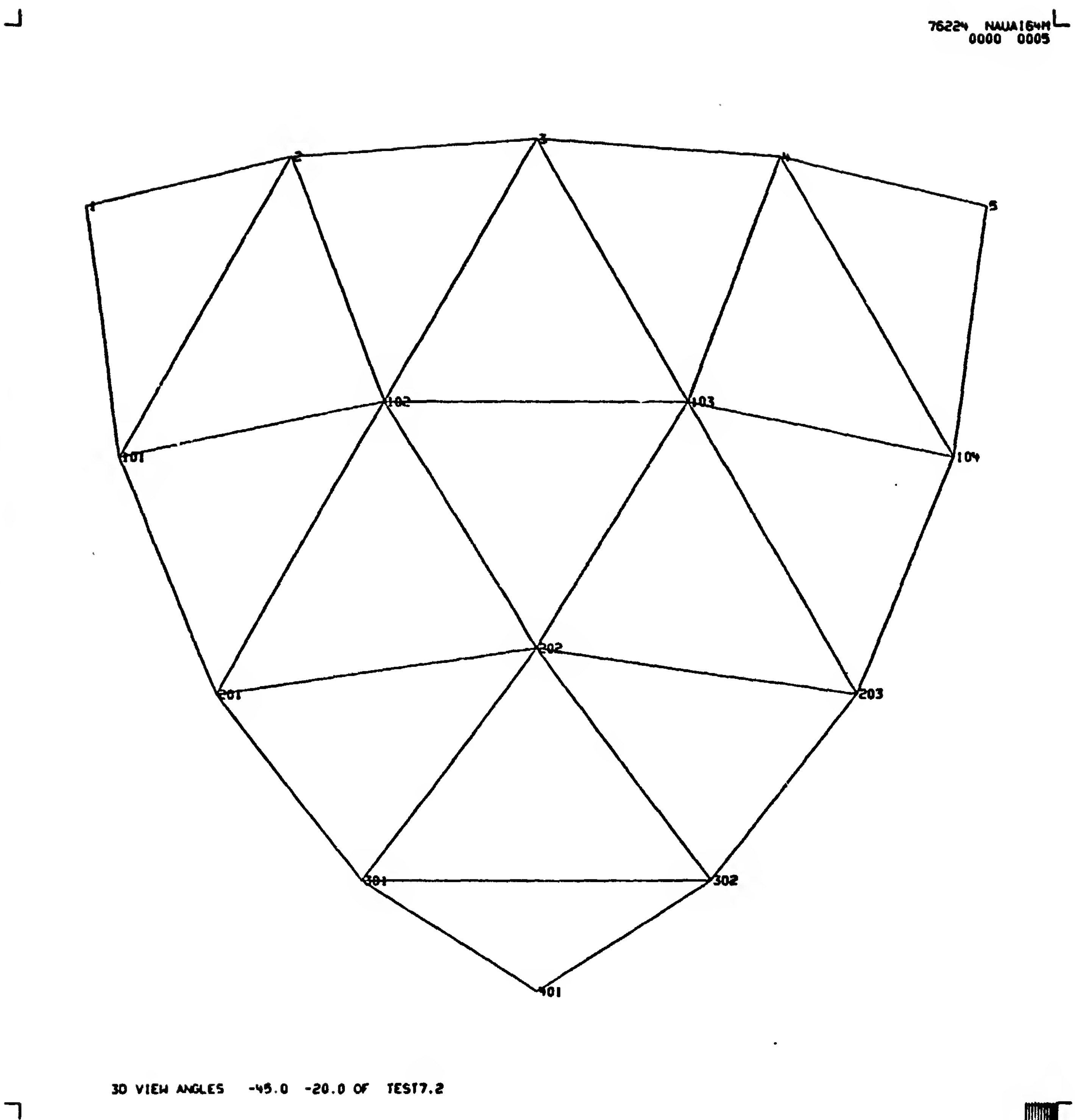
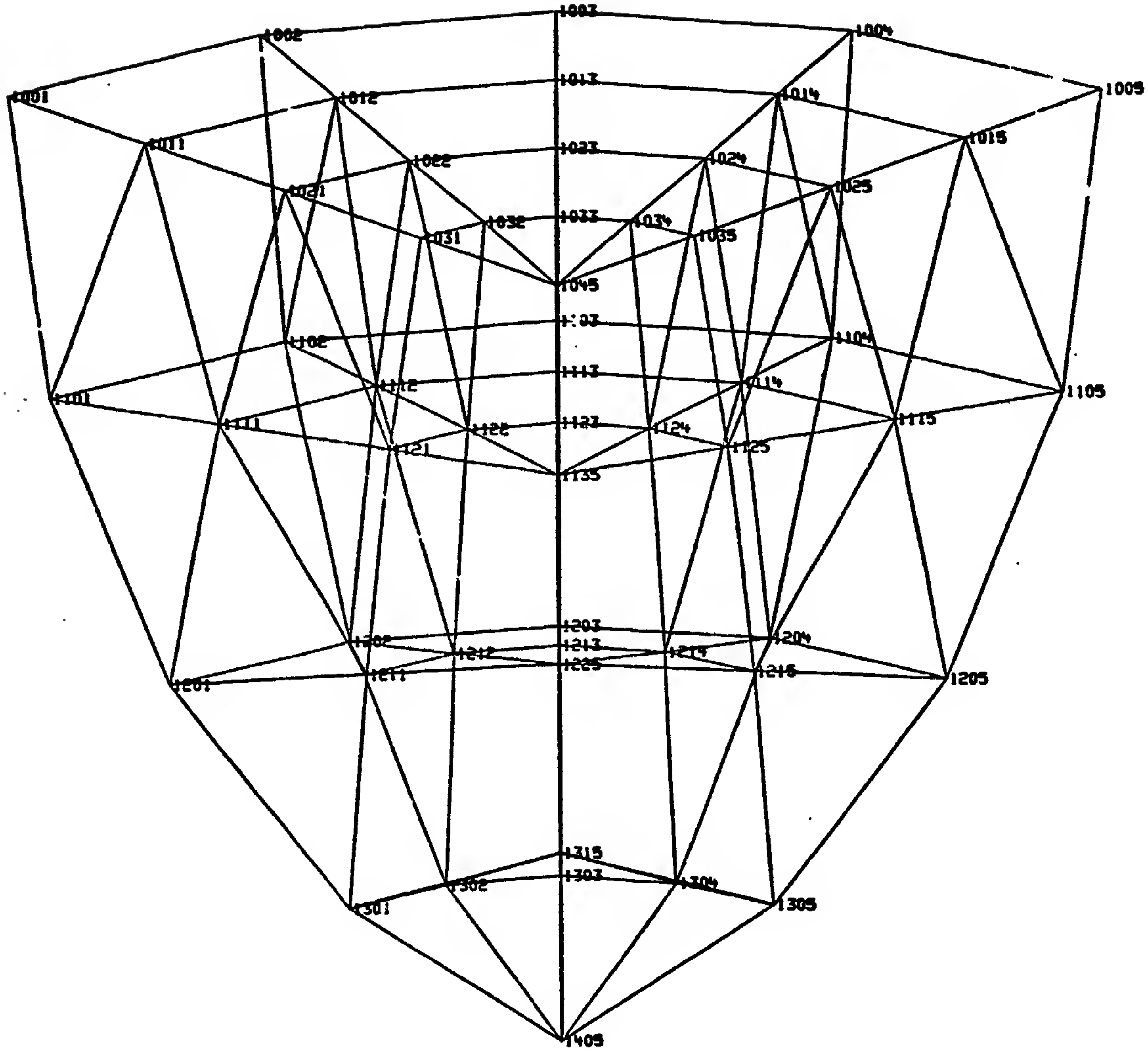

1
2
3
4
101
102
103
104
201
202
203
302
2D VIEW ANGLES 0.0 0.0 OF TEST7.2

FIGURE 7.4



76224 NAUA164M
0000 0005
1
2
3
4
5
101
102
103
104
201
202
203
301
302
401
3D VIEW ANGLES -45.0 -20.0 OF TEST7.2

FIGURE 7.5



3D VIEW ANGLES -45.0 -20.0 OF TEST7.2

FIGURE 7.6

SAMPLE PROBLEM 8.1

8.1.1 Description:

To model a 15° segment of the SRI tank. The tank is composed of two sections, the top 5 inches are a cylinder, r=5, and the last 5 inches are a hemisphere. The upper portion of the tank will be modeled using the TFULL shape. The bottom section will use TANK and CAPFLUID shapes. Figure 8.1 illustrates the model desired.

8.1.2 MESHLAN Program:

```
MØDEL SRITANK1
GEØMETRY
    SHAPE = TFULL
    BØUNDARY = FUNCTIØN 1 (8.66)
GRAV = 200
MESH(5010,1012)
STEP Z FRØM 10.0 TØ 8.66 BY 2
        NUMBER GRIDS BY 1,ELEMENTS BY 1
        FIX 123456 AT (10.0)
            ELEMENTS = QUAD2,1
                PRØPERTY = 100
STEP Z FRØM 8.66 TØ 5.0 BY 4
    SHELL
        NUMBER GRIDS BY 1,ELEMENTS BY 1
            ELEMENTS = QUAD2,3
                PRØPERTY = 100
    SØLID
        NUMBER GRIDS BY 1,ELEMENTS BY 100
            ELEMENTS = FHEX2,301
                PRØPERTY = 200
STEP THETA FRØM 0.0 TØ 15.0 BY 1
    SHELL
        NUMBER GRIDS BY 1000,ELEMENTS BY 1
    SØLID
        NUMBER GRIDS BY 1000,ELEMENTS BY 1
DIVIDE R BY 8
        NUMBER GRIDS BY 1-0,ELEMENTS BY 1
PLØT 180.,10.
ENDM

MØDEL SRITANK2
GEØMETRY
    SHAPE = TFULL
    BØUNDARY = FUNCTIØN 2
GRAVITY = 200
MESH(5016,1016)
DIVIDE Z BY 5
```

```
    SHELL
        NUMBER GRIDS BY 1,ELEMENTS BY 1
            ELEMENTS = QUAD2,7
                PRØPERTY = 100
    SØLID
        NUMBER GRIDS BY 1,ELEMENTS BY 100
            ELEMENTS = FHEX2,701
                PRØPERTY = 200
STEP THETA FRØM 0.0 TØ 15.0 BY 1
    SHELL
        NUMBER GRIDS BY 1000,ELEMENTS BY 1
    SØLID
        NUMBER GRIDS BY 1000,ELEMENTS BY 1
DIVIDE R BY 8
        NUMBER GRIDS BY 100,ELEMENTS BY 1
PLØT 180.,10.
ENDM

MØDEL SRITANK3,SAVE,NEW
GEØMETRY
    SHAPE = CAPF
    BØUNDARY = FUNCTIØN 3
MESH(,1021)
DIVIDE Z BY 8
    NUMBER GRIDS BY 1,ELEMENTS BY 100
        ELEMENTS = FHEX2,1201
            PRØPERTY = 200
STEP THETA FROM 0.0 TO 15. BY 1
    NUMBER GRIDS BY 1000,ELEMENTS BY 1
DIVIDE R
    NUMBER GRIDS BY 100,ELEMENTS BY 1
PLØT 180.,-10.
ENDM

MØDEL SRITANK4,SAVE
GEØMETRY
    SHAPE = TANK
    BØUNDARY = TABLE 50
MESH(5021)
DIVIDE Z
    NUMBER GRIDS BY 1,ELEMENTS BY 1
        ELEMENTS = QUAD2,12
            PRØPERTY = 100
STEP THETA FRØM 0.0 TØ 15.0 BY 1
    NUMBER GRIDS BY 1000,ELEMENTS BY 1
PLØT 180.,10.
ENDM

MØDEL SPRITANK5
GRAVITY = 200
FIND BØUNDARIES SRITANK4,SRITANK3
PUNCH
ENDM
```

NOTES: a. SRITANK3 is to be saved on a SAVE file declared NEW in order to generate CFLSTR Bulk Data later.

b. SRITANK4 is added to the SAVE file.

c. SRITANK5 retrieves the structure (SRITANK4) and fluid (SRITANK3) models from the SAVE file and generates CFLSTR cards for their union.

8.1.3 Model:

Figure 8.1 defines the model desired. The MESHGEN plots generated, as defined in the MESHLAN programs above, are shown in Figures 8.2 - 8.7.

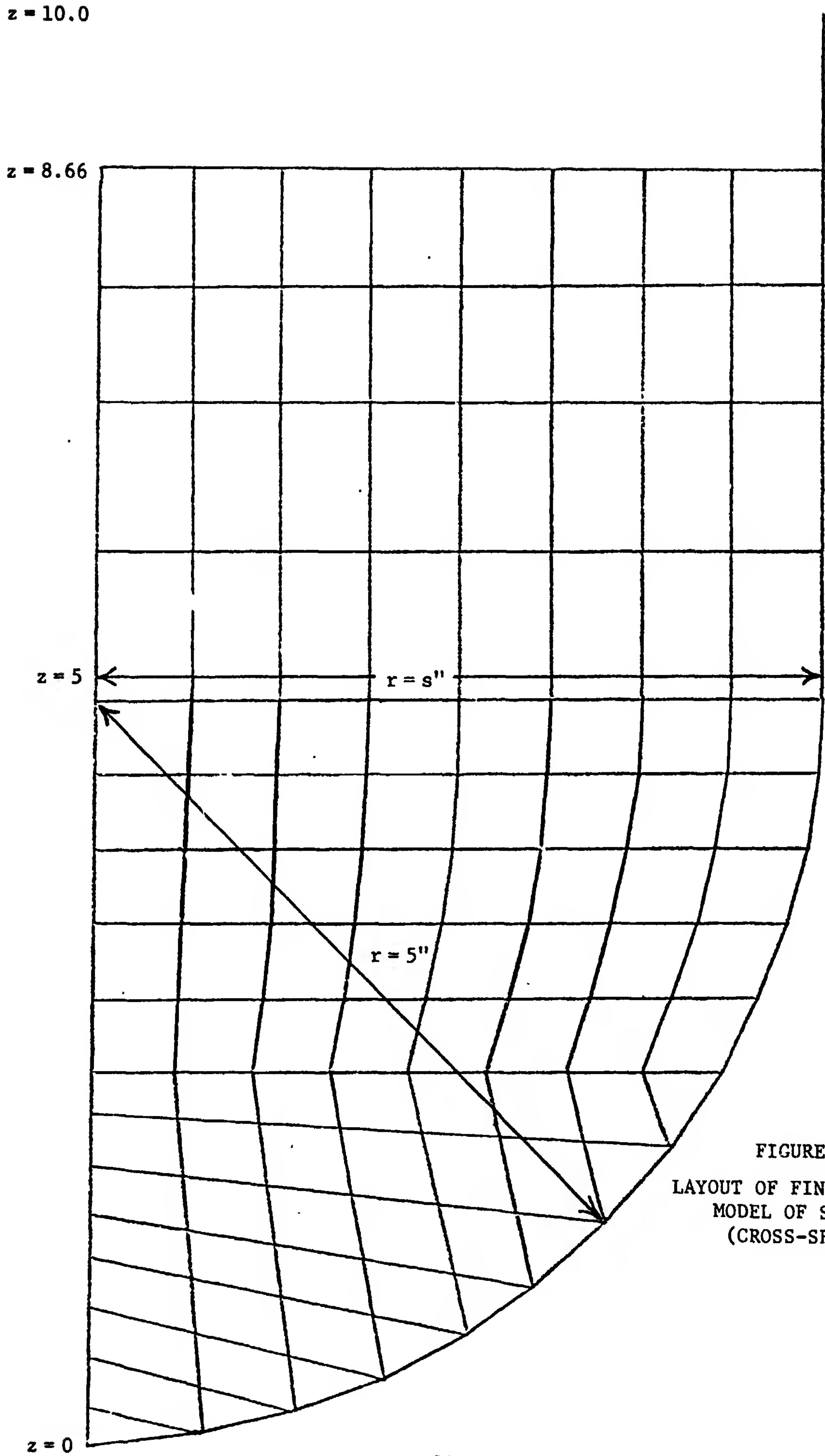


FIGURE 8.1

LAYOUT OF FINITE ELEMENT
MODEL OF SRI TANK
(CROSS-SECTION)

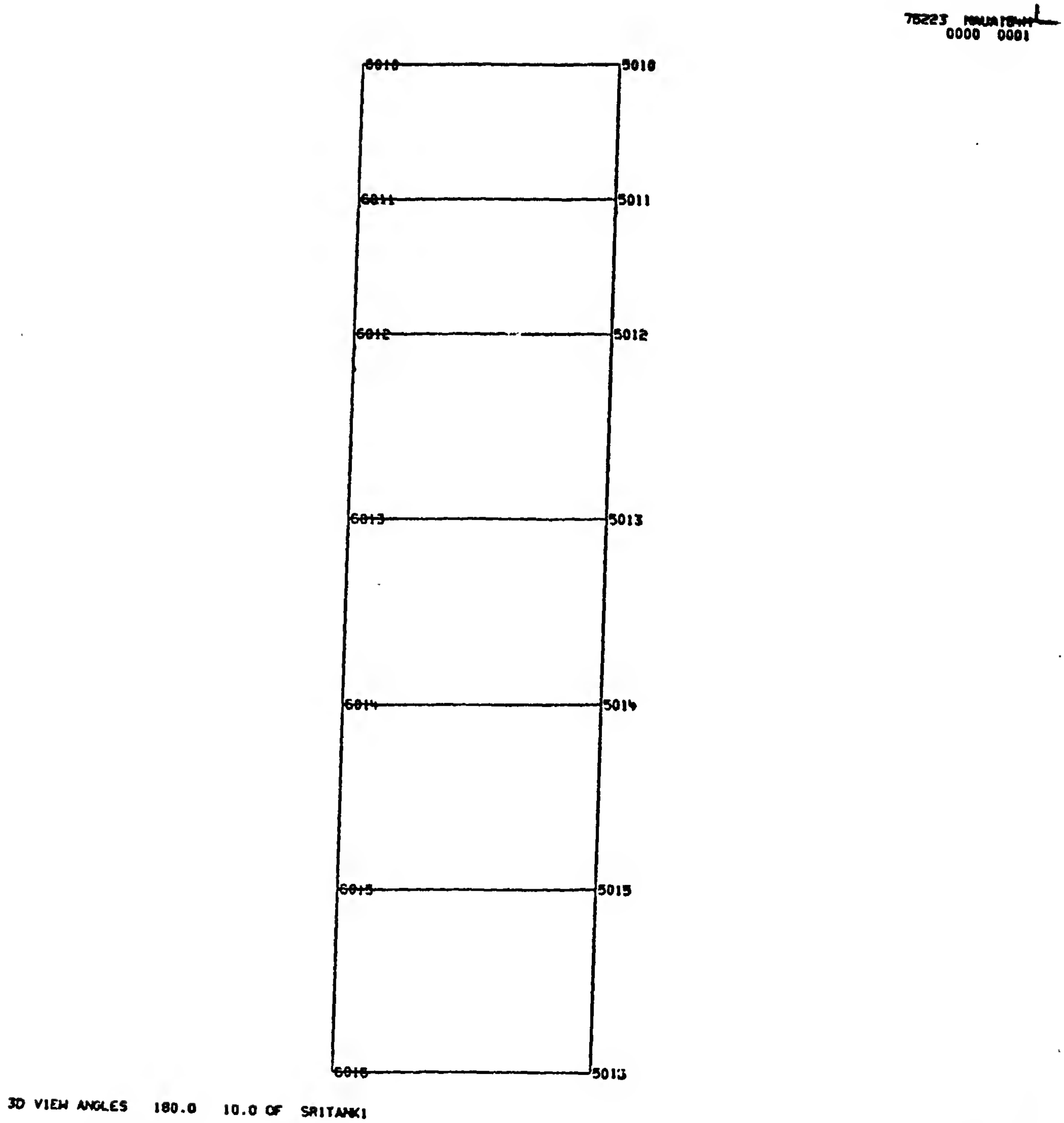
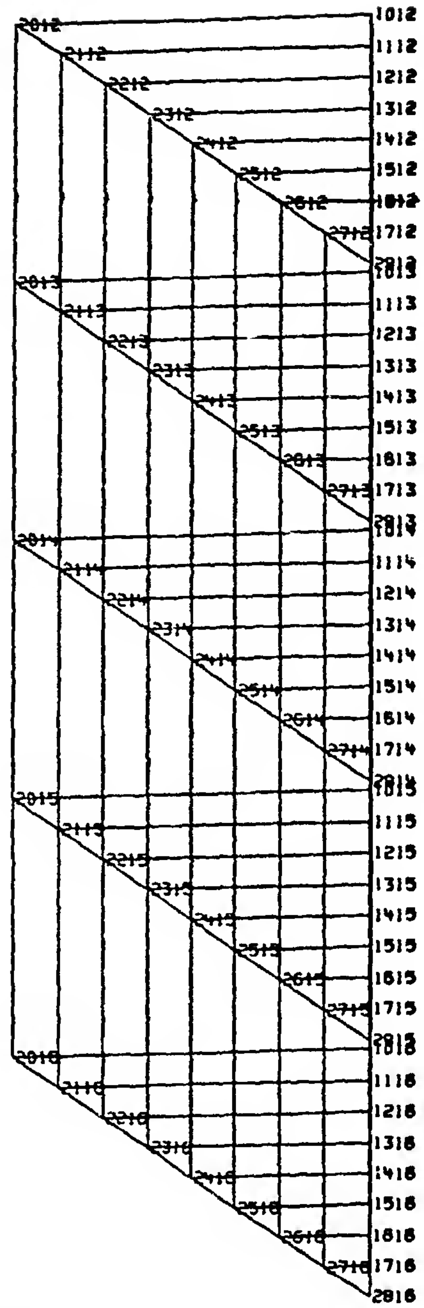

76223
0000 0001
5010
5011
5012
5013
5014
5015
5013
3D VIEW ANGLES 180.0 10.0 OF SRITANK1

FIGURE 8.2



30 VIEW ANGLES 180.0 10.0 OF SRITANKI

FIGURE 8.3

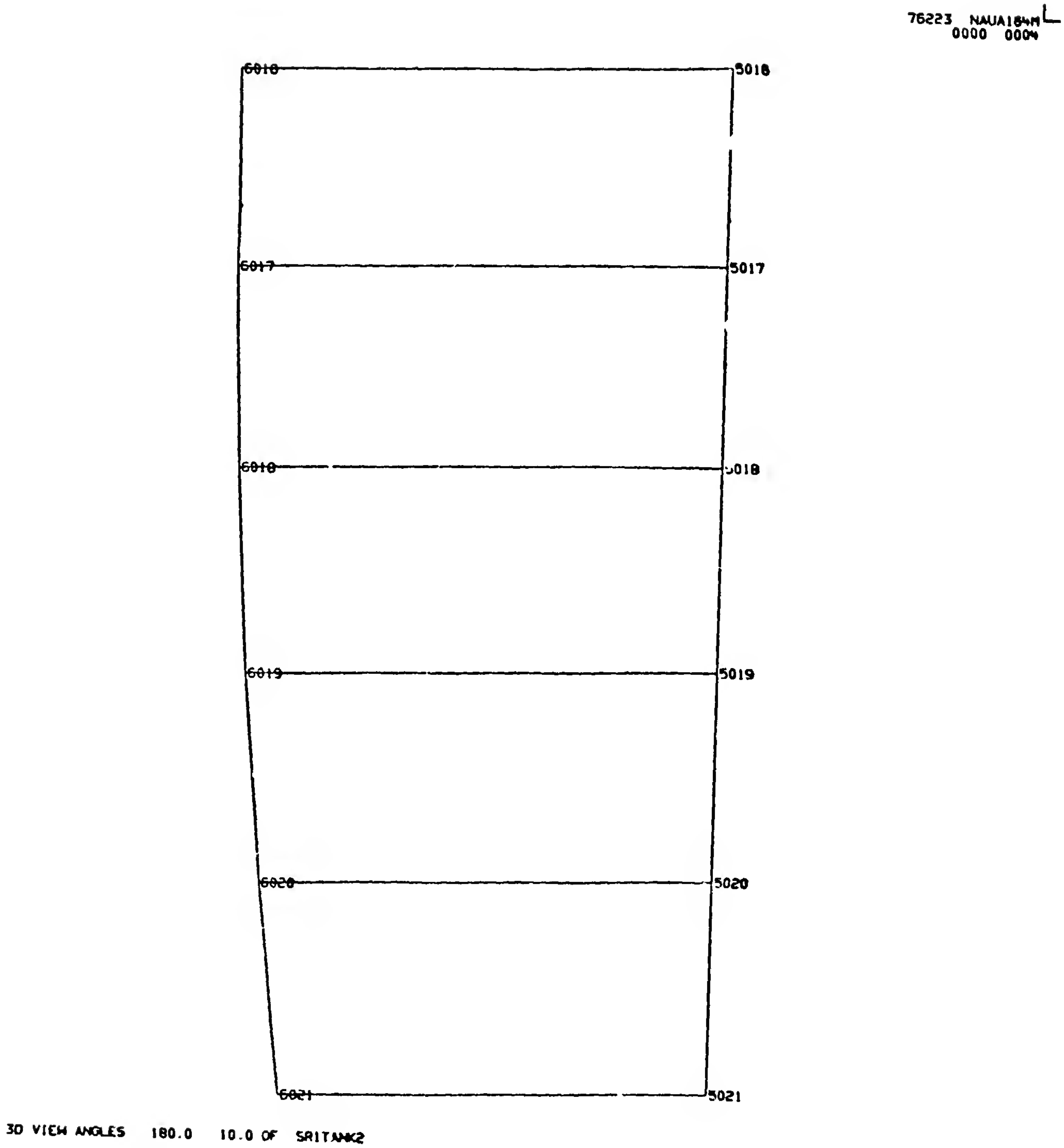
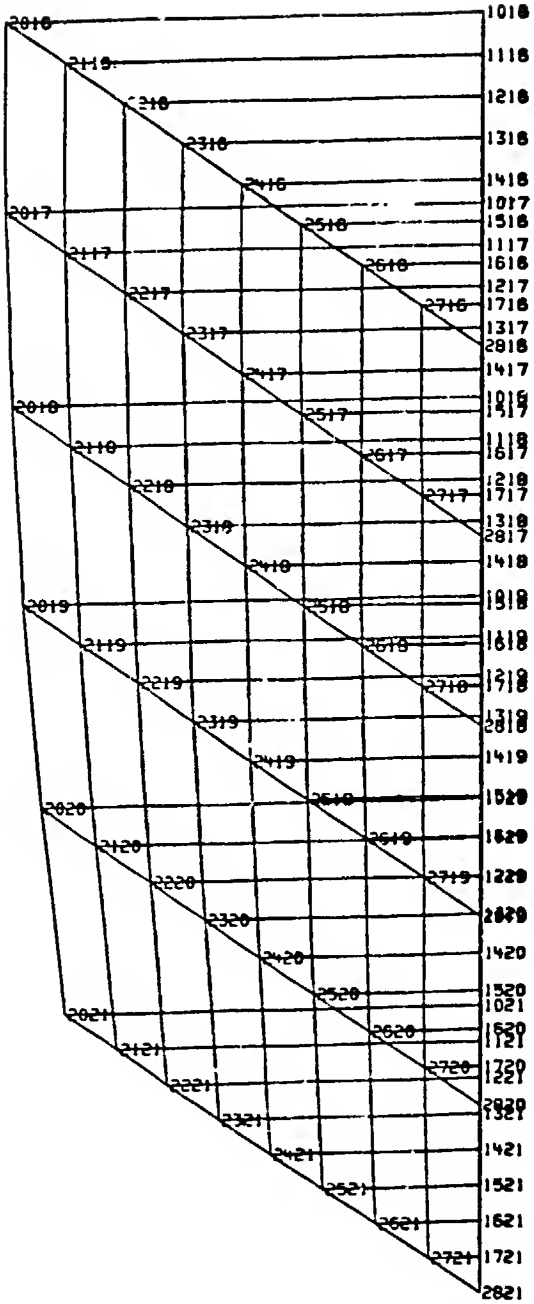

76223 NAUA184M
0000 0004
6016
5016
6017
5017
6018
5018
6019
5019
6020
5020
6021
5021
3D VIEW ANGLES 180.0 10.0 OF SRITANK2

FIGURE 8.4

76223 NAUAI64M
0000 0005



3D VIEW ANGLES 180.0 10.0 OF SRITANK2

FIGURE 8.5

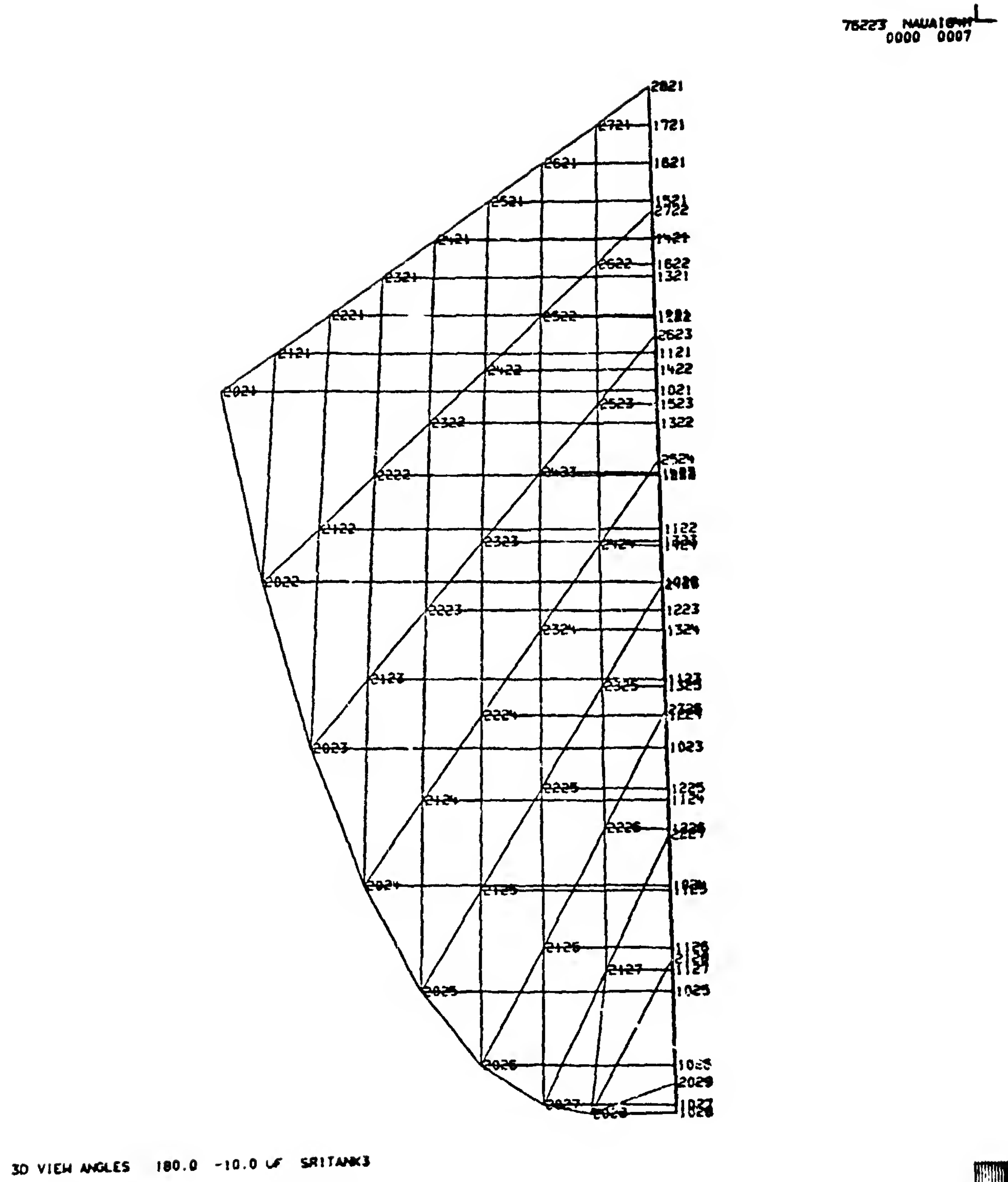
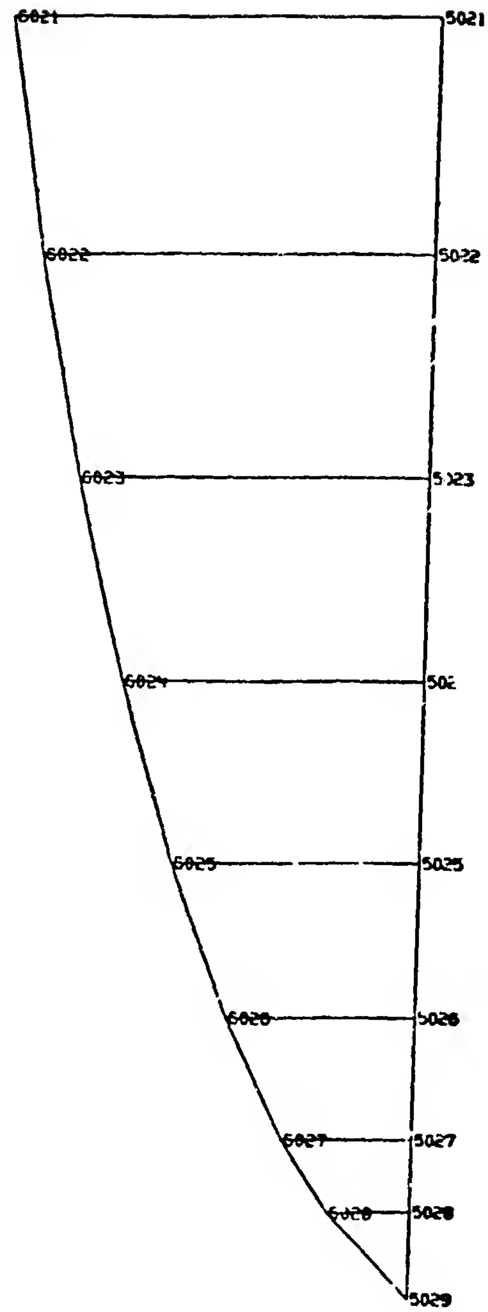

0000 0007
1721
1621
2721
2621
2521
2722
2421
2622
1622
1321
2321
2221
2522
2623
2121
1121
1422
2422
2021
1021
1523
2523
2322
1322
2222
2524
1122
2323
2122
2022
1223
2223
2324
1324
2123
2325
2224
2023
1023
2225
2124
2226
2024
2125
2126
2127
1127
2025
1025
2026
2029
2027
3D VIEW ANGLES 180.0 -10.0

FIGURE 8.6

76223 NAVAI8HH
0000 0099



3D VIEW ANGLES 190.0 10.0 OF SRITANKY

FIGURE 8.7